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SEP 80 J V ZACCOR, C WILTON, G SHEPHARD DCPA01-78-C-0278
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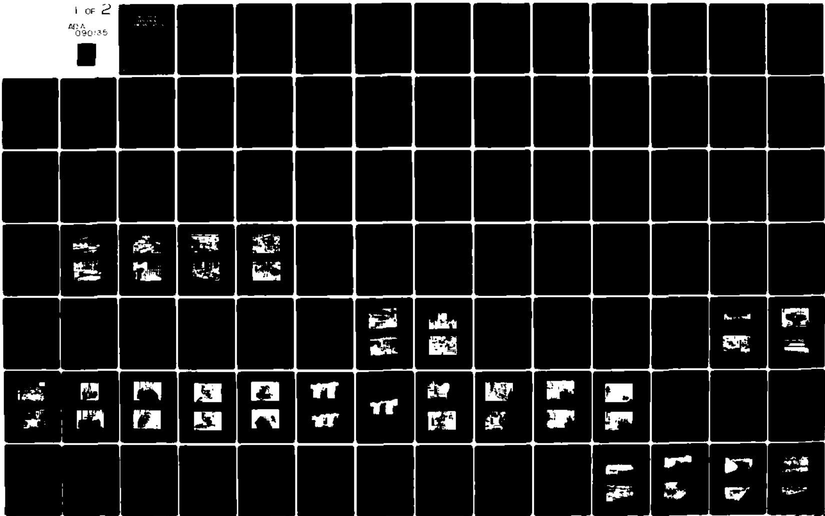

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INDUSTRIAL HARDENING DEMONSTRATION

FINAL REPORT

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Contract No. DCPA01-78-C-0278
Work Unit 1124D

SCIENTIFIC SERVICE, INC.

Unclassified

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testing; self-help manual; U.S. industry; industrial vulnerability; nuclear event; analytical procedures; hardening exercises; logistic requirements

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The report describes the initial testing of a self-help manual developed for application by U.S. industry to help reduce its vulnerability to a nuclear event; it is expected to have application to natural disasters as well.

The completed program constitutes the first two phases of a multi-phased effort to evaluate the general concepts in the manual. In the

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first phase, purely analytical procedures were used to test the principles and techniques. These were applied at a number of industrial sites by personnel familiar with weapons effects and at a few of the same plants by in-plant personnel unexperienced with weapons effects; the results are compared. In the second phase, actual hardening exercises were carried out, both by personnel familiar with the manual and also by plant personnel entirely unassisted. These operations were documented with slides and/or movies, and information was obtained on time and personnel logistic requirements to complete the hardening efforts. Results of the analyses are presented and comparisons made which suggest significant benefits from self-help industrial hardening might be expected..

Additional phases are both planned and necessary. The self-help manual can only be developed into a practical tool through an iterative process involving input from industry and from weapons effects experts working together. Thus, additional plants need to be involved to obtain statistical data on variation in hardening potential and benefits, and to identify especially vulnerable industries and develop alternative options for these. Key concepts need to be tested in the field under blast loading conditions to ensure validity.

(DETACHABLE SUMMARY)

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INDUSTRIAL HARDENING DEMONSTRATION

by

J.V. Zaccor, C. Wilton, and G. Shephard, Jr.

for

Federal Emergency Management Agency
Washington, D.C. 20472

Contract No. DCPA01-78-C-0278, Work Unit 1124D
Dr. Michael A. Pachuta, Project Officer

FEMA REVIEW NOTICE:

This report has been reviewed in the Federal Emergency Management Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Federal Emergency Management Agency.

Scientific Service, Inc.
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A

(DETACHABLE SUMMARY)

INDUSTRIAL HARDENING DEMONSTRATION

The report describes the initial testing program to evaluate a manual developed to enable U.S. industry to reduce its vulnerability to nuclear attack and to some aspects of natural disasters. The manual describes a process called industrial hardening, which includes any method to enable a facility to resist fire, missile, blast, and electro-magnetic pulse (EMP) damage to vital equipment; planning and execution are to be implemented entirely as a self-help program. The objective of this study was to test the feasibility of the industrial hardening and self-help concepts through analytical exercises conducted by individuals proficient in weapons effects and disaster analysis and by local plant personnel with little or no background on the subject, and to compare the two. These exercises assessed the vulnerability of industrial plants both before and after hardening, estimating the time and effort required to achieve the vulnerability reduction. These were then checked against data obtained by conducting hardening exercises. The information obtained provides a quantitative measure of the potential significance of industrial hardening as well as initial input on how close to that potential a self-help program might come. The data are summarized in the attached tables.

Ten plants representing different industries were studied, and analyses were completed at nine that were extensive enough to yield assessments of the change in vulnerability. The increase in resistance to nuclear attack ranged from 6 to 18 psi at six plants; two plants were rendered essentially invulnerable because of complete removal to a host area; and one plant's vital operations were all rural already so that loss of this plant would not have appreciable effect on production. To give some idea of the effectiveness of this change, consider that even the smallest change (from 2 to 8 psi) would reduce weapon effectiveness

for industrial damage by approximately 84% (i.e., the 8 psi ring around ground zero is only 16% of the area of the 2 psi ring).

In the second phase of the program, hardening exercises were conducted at four plants. Slides and/or movies were made of the operations conducted at three of these plants, one of which was done by Scientific Service, Inc. (SSI) personnel in several stages in order to obtain pictures. At the other plants, the owner/managers did all the planning (in advance) and two of these outlined proposed hardening operations to SSI personnel so that the cameras could be set up to document the hardening exercise. The exercises were conducted entirely by in-plant personnel and completed in one day.

VULNERABILITY CHANGE DUE TO HARDENING AS AN INCREASE
IN OVERPRESSURE EXPECTED BEFORE MODERATE DAMAGE RESULTS TO KEY EQUIPMENT

Plant	Before Hardening (psi)	SSI Assessed Improvement (psi)	In-Plant Personnel Assessed Improvement (psi)	After Hardening (psi)
Metal Caster	2	6	3	8
Electrical Equipment Manufacturer	2	18	—	20
Metal Stamping	2	14	—	16
Steel Fabrication	2	8	—	10
Food Processor	2	invulnerable[a]	—	invulnerable[a]
Utility	?[b]			
Wood Products Manufacturer	2	18	—	20
Small Job Shop	2	invulnerable[c]	(c)	invulnerable[c]
Electronic Equipment Manufacturer	2	invulnerable[c]	—	invulnerable[c]
Precast Construction	2	5	15[d]	17

— Not attempted; SSI assessment only

(a) Mandatory food processing operations of this company all take place in rural areas, and only final "convenience" packaging takes place in this plant. Some of the equipment could be readily salvaged for other uses by other plants, but such analysis was outside the scope of the present study.

(b) Not analyzed or assessed because this utility's resources are already well dispersed geographically.

(c) Moved to host area, where overpressure is presumed to be 2 psi. If host area is not targeted, it may be assumed that these two plants have become "invulnerable".

(d) The proprietor was innovative, deciding to enter a new business in the post-attack environment wherein his most vulnerable equipment would no longer be needed, hence the discrepancy between assessed improvements.

COMPARISON OF ESTIMATED AND ACTUAL PLANNING AND EXECUTION TIMES

Plant	Planning Effort				Estimated Phase II Effort			Actual Hardening Effort			
	Man-Hours Phase I	Man-Hours Phase II[a]	Number of Men	Elapsed Time (hrs)	Man-Hours	Number of Men	Elapsed Time (hrs)	Man-Hours	Number of Men Used/Avail.	Elapsed Time (hrs)	% of Plant Hardened
Wood Products Company	4	4	2	8	500[b]	24	36	Staged for movies			20
Small Job Shop	15	1	1	16	12	2	6	14	2/2	7	100
Electric/ Electronics Manufacturer	Unknown				Not estimated[c]			64	8/16	8	100
Precast Concrete Yard	12	3	1	15	16	4	7	24	4/6	10	100

(a) Logistic planning for hardening operations.

(b) One hundred hours if sandbags were filled in advance; forty hours if equipment skidded into a ditch, covered with heavy plastic, and protected with backfill.

(c) Four men required five days to relocate entire plant and return it to full production. It was estimated that evacuation required forty percent of this effort.

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ACKNOWLEDGEMENTS

We should like to thank Dr. Michael Pachuta of FEMA for supporting this effort and for taking his role of critic seriously. Through his insistence, this effort presents some of the attitudes of industrialists heretofore missing in discussions, but which are necessary to provide insight into industry's response to industrial preparedness.

Dr. Pachuta and the authors find it impossible to thank adequately those in industry who provided access to plants, information, time and effort. Without participation and input from industry at all levels, it is highly unlikely that a practical self-help manual could ever be developed and tested. To the many individuals who gave unstintingly of their time to help evaluate the concept of self-help for industrial preparedness, we apologize for not thanking each of them individually here. Their efforts in reading the manual and in providing comments and criticisms are, nevertheless, greatly appreciated.

We also wish to acknowledge a special indebtedness to those who participated in hardening exercises so that we could record these implementations on film and determine reasonable time and materials requirements. We need many more such contributors and exercises.

Finally, we should like to thank Bill Sugg and George Kamburoff for locating industrial participants; George Kamburoff and Joe Boyes for conducting the many hardening analyses; Joe Boyes and Mike Reeder for their photographic support; Maureen Ineich for the considerable artwork involved in producing slides, films, and reports; and Evelyn Kaplan and Larue Wilton for putting up with the many revisions and for providing the time-consuming but necessary editing support.

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Section 1
INTRODUCTION

BACKGROUND

This report summarizes the initial testing phases of a prototype manual, which was designed to provide a practical procedure that can be applied by industry to reduce vulnerability to nuclear weapons effects and to some aspects of natural disasters. This ongoing program to test the self-help concept and to provide a basis for upgrading of the manual is being conducted by Scientific Service, Inc., for the Defense Civil Preparedness Agency (now, Federal Emergency Management Agency) under Contract No. DCPA01-78-C-0278.

A general description of the contents and objectives of the manual being tested is important to an understanding of the test program. The manual was developed by Scientific Service, Inc., for the Defense Civil Preparedness Agency, under an earlier program.* This manual is designed as a guide for industrial personnel in planning and executing programmed activities that use plant resources to reduce the vulnerability of plant equipment to nuclear threats and to comparable aspects of natural disasters. The process of reducing vulnerability within industry in general has been termed "Industrial Hardening" and is described briefly below.

As used in this report industrial hardening includes any methods to protect against fire, missile, blast, and electromagnetic pulse (EMP) hazards. Such methods include: removal of combustibles and potential missiles; strengthening or shielding of equipment against missiles and

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* "Crisis Relocation Industrial Hardening Plan," SSI Report No. 7729-4, Scientific Service, Inc., Redwood City, California, June 1979. (Working Draft).

blast, or evacuating equipment to relatively risk-free areas; disconnecting equipment from antennas and power lines. To describe these different options, help define resource requirements to implement the options, and provide the benefit of decentralized management of a myriad of component tasks, the manual was developed as an integrated collection of booklets. Each booklet directs an activity and is intended to be self-contained with respect to instructions, examples, and worksheets.

The booklets generally guide users in methods to assess, gather, and commit resources more efficiently. Important elements of the process include determining the relative importance and vulnerabilty of each item of equipment, establishing priorities for hardening, and developing a range of options for hardening facilities and equipment based on those techniques most appropriate to local circumstances.

The research efforts reported here are part of a comprehensive program that must be completed before industrial protection can be applied on a national scale. Five program elements necessary to this overall program are as follows:

I. Make an initial, general analytical assessment.

A. Determine the vulnerability of several different kinds of plants before and after hardening and estimate the time and effort required —

1) As an analytical exercise conducted by individuals proficient in evaluating nuclear weapons effects;

2) As an analytical exercise conducted by local plant personnel not knowledgeable in the subject.

B. Analyze the differences between I A 1) and I A 2); interview the in-plant analysts and attempt to identify the reasons for differences; and recommend changes in the manual that would reduce these differences.

II. Make an initial, general experimental assessment.

A. Conduct hardening exercises (preferably at the same plants) to determine actual times and material and personnel resources required to harden.

B. Record the hardening exercises on film for future development as training films, for public relations, etc.

C. Analyze the differences between II A and I A; use the analysis to improve estimates of vulnerability changes generally achievable.

III. Conduct laboratory and field tests of selected hardening methods to obtain experimental data on hardened vulnerabilities.

A. Conduct shock tube studies to establish dynamic and overpressure damage levels for selected hardening schemes. For example,

1) Examine the effect of placing industrial equipment in a channel between two berms as a function of channel width and berm height.

2) Evaluate the effect of banding or welding clumps of equipment together on the anchoring requirements.

B. Conduct field tests on full-size equipment to verify the shock tube studies.

IV. Conduct a statistical assessment.

A. Conduct both analytical and experimental assessments of hardening at a statistically significant cross-section of plants, for one or more specific industries.

B. Identify the important differences and similarities insofar as hardening to reduce vulnerability is concerned.

C. Extrapolate the above data to assess the nationwide impact of a nuclear attack insofar as selected industries are concerned.

D. Consider the merit of applying or developing a general procedure for extrapolating to assess all industry.

V. Conduct an analytical assessment of the vulnerability of the entire U.S. industry before and after hardening.

Other elements of this comprehensive program should include the specific problems of critical or essential facilities; i.e., those industries or organizations that are necessary to support military requirements and the crisis relocation program. These will require hardening techniques to allow operation of the equipment and processes during the crisis period and will necessarily include key worker shelters.

OBJECTIVES

The principal objectives of the Phase I and Phase II efforts, which were the subject of this work, were to make initial tests of the feasibility of the self-help concept and to assess the expected gain from industrial hardening. These tests and assessments depend on identifying and answering as many questions as possible regarding the effectiveness and practicability of the manual in actual use.

Perhaps an equally important factor in such a program is one that is scarcely mentioned; i.e., the problem of getting participation by industry. Not many in industry have either the interest or the time to be bothered with the questions of nuclear or other disasters for the simple reason that they seem remote possibilities. Hence, developing industry interest and response is virtually as important as developing a plan. Appendix A provides two accounts of industry first encounters, plus the rationale for the response of a third industry contact. Of course, some of these will be successful and some will not. In order to get on with

the manual evaluation process, we have not investigated the reasons for the different attitudes — which is a complex subject in itself; rather, we have built on those situations where the response was positive.

The specific objective of Phase I was to initiate analytical testing of the industrial hardening manual — both by those proficient and by those inexperienced in weapons effects — to determine the gap between them in applying it. An inherent part of this task was to use the information to establish what sorts of changes would be needed to bring these closer together so that such changes eventually could be incorporated into the manual to improve it.

The specific objective of Phase II was to conduct hardening exercises to obtain slides and/or movies of typical hardening options (i.e., evacuation, hardening in place, moving and hardening) and to conduct a complete testing of the manual entirely with in-plant personnel. An inherent part of this task was to obtain hard data on time and manpower required, and to make comparisons of this empirical data with planning estimates to evaluate how realistic the estimates might be.

Section 2
METHODS

PHASE I

The ground rules applied for the Phase I assessment of the manual were keyed to the Phase I objective; i.e., a comparison of the "outcome" obtained when the manual was applied by those proficient in weapons effects (but unfamiliar with the plants) with the "outcome" when it was applied by plant personnel uninitiated in weapons effects (but completely familiar with the plant).

The outcome was entirely the result of a paper exercise involving estimation of time and materials to be allocated to complete the hardening tasks using materials and personnel on hand. The measure of outcome was principally the change in vulnerability achieved.* Essentially the only constraint imposed for these analyses was to schedule a three-day phased withdrawal of plant personnel to the "host area". The phased relocation was presumed to evacuate 20%, 50%, and 90-95% of plant personnel by days one, two, and three, respectively.

Evaluation of overall changes in overpressure vulnerability that might be achievable by following the manual were taken as measures of the outcome. In assigning vulnerabilities, probabilities of occurrence of damaging events were not considered. Therefore, if a reasonable potential existed for damage from some kind of event, then it was assumed damage

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* The change in vulnerability is determined in the process of applying the manual and is different for each piece of equipment. However, as a single index for the entire plant, the difference in ratings for the most vulnerable items necessary to production before and then after hardening is probably suitable.

would occur unless some action were taken. (Rigorous statistical treatment would be required to go further than this and define the frequency with which damage actually does occur. Such statistical treatment is at least an order of magnitude greater effort and entirely outside the scope of the current program.) The approach taken at this stage is conservative.

Booklets that are incorporated in the manual, or planned, are indicated in Figure 1. Two of these (Booklets #6 and #10) have not yet been completed, so only eight have been tested. (Completion of the two missing booklets is dependent on the output from a study of methods for upgrading structures. For the current effort, visits to industrial plants by SSI personnel provided an expedient temporary alternative.) Based on the observation that most plants use light-steel-framed, metal-paneled structures to house equipment, SSI personnel analyzed several of these and found that, generally, they are likely to be demolished at about 2 psi. Because there is reasonable potential the collapsing structure will become the source of principal damage to industrial equipment within, under our ground rules it is assumed this equipment is vulnerable at 2 psi. Consequently, in lieu of a booklet on structural analysis, 2 psi was stipulated to in-plant personnel of the plants visited to be used as the collateral damage potential.

Figure 2 (from Booklet #5, page 8) depicts the format used in the manual for cataloguing the equipment in an industrial plant; Figure 3 (from Booklet #7, page S) depicts the corresponding format for establishing hardening priority; and Figure 4 (from Booklet #7, page 8) depicts the format for hardening decisions. In Figure 3, the number entered in the "Priority" column establishes the order for hardening activities: the lower the number, the higher the ranking for hardening attention at the stage depicted in Figure 4.

When the analysis is done well in advance, there is ample opportunity for evaluating alternatives and for making maximum use of hardening resources, which are catalogued on worksheets in another booklet (see

CRISIS RELOCATION INDUSTRIAL HARDENING PLAN

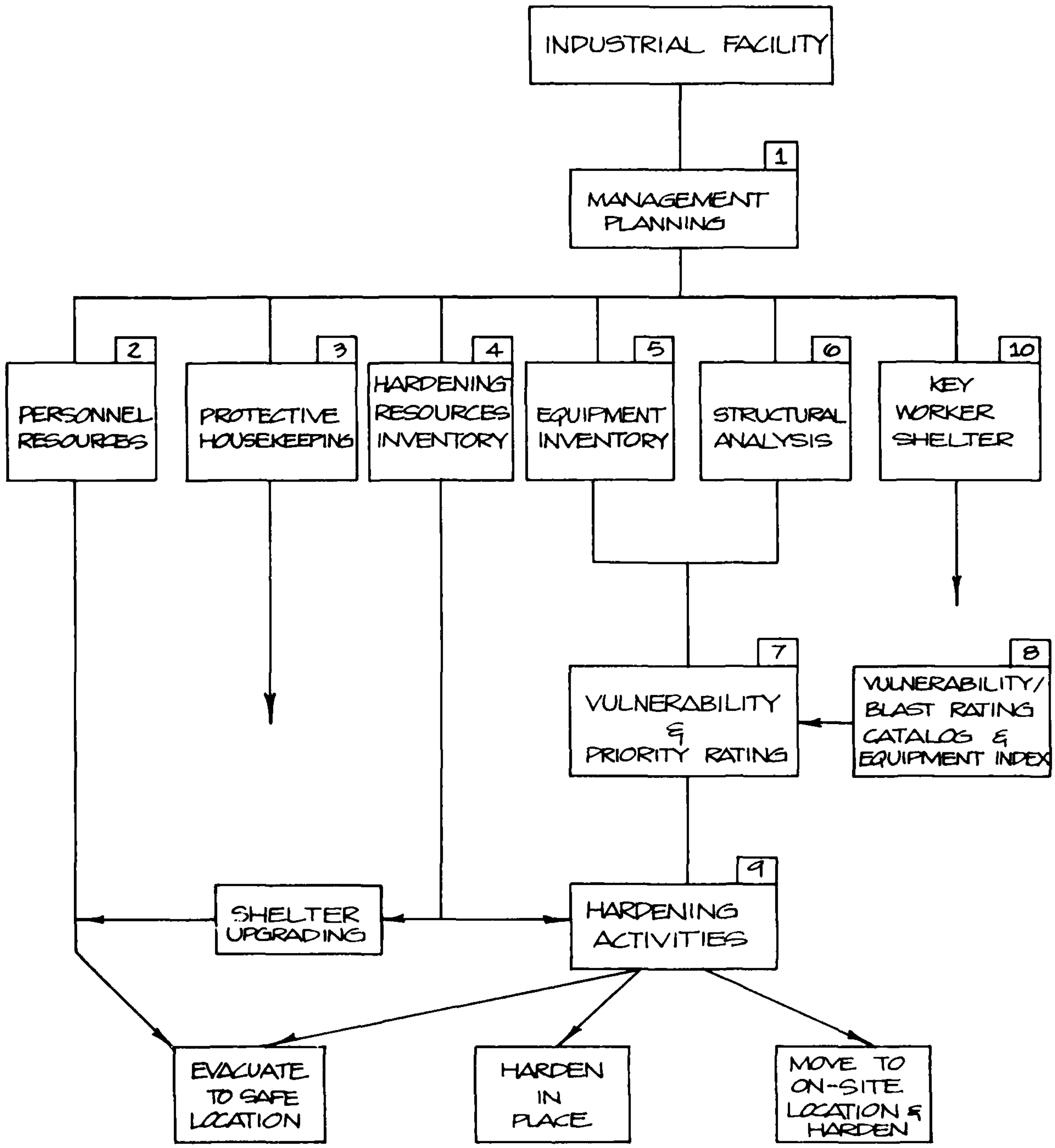

Figure 1. Flow Chart of Industrial Hardening Plan.

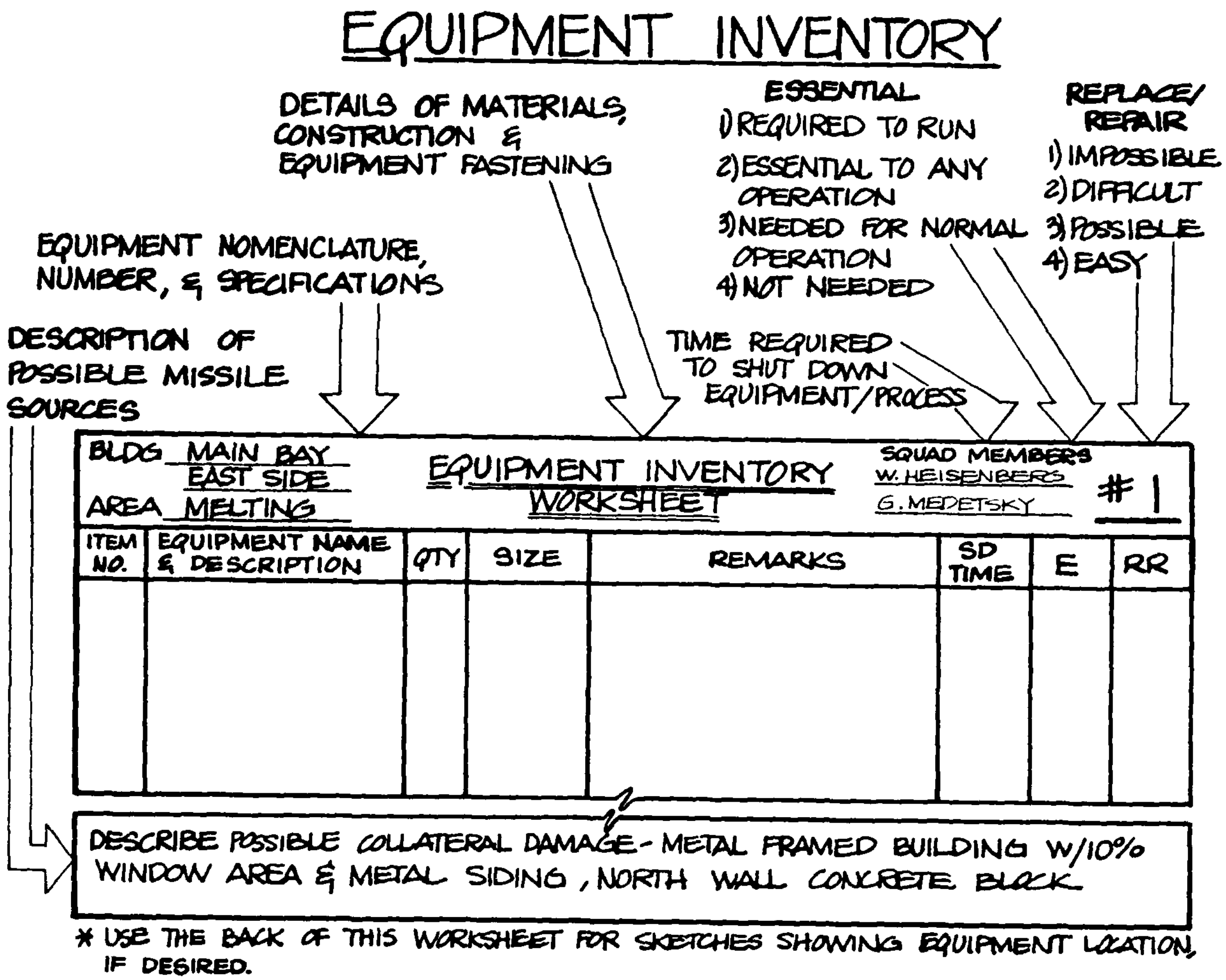

Figure 2. Equipment Inventory Format.

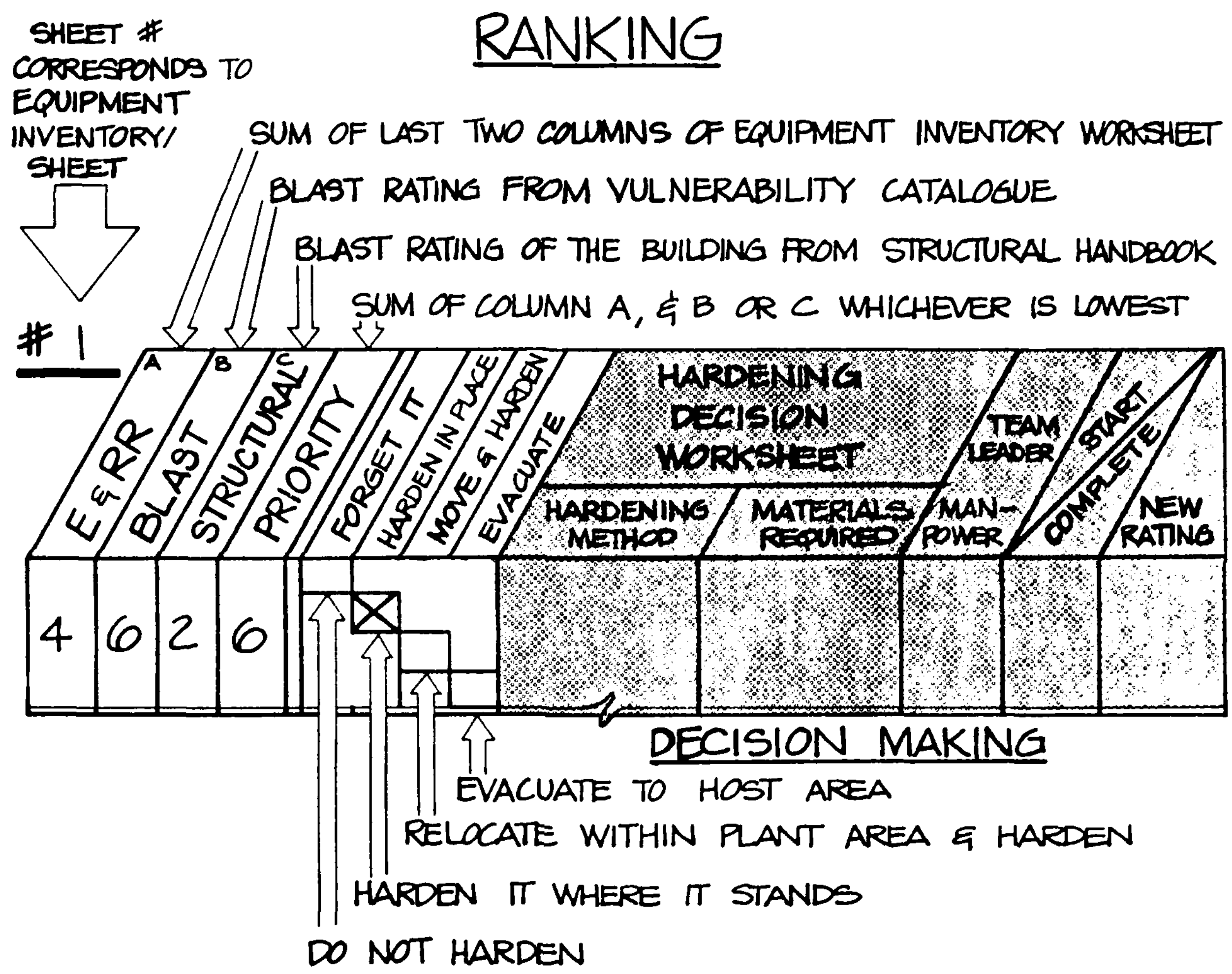

Figure 3. Hardening Priority Format.

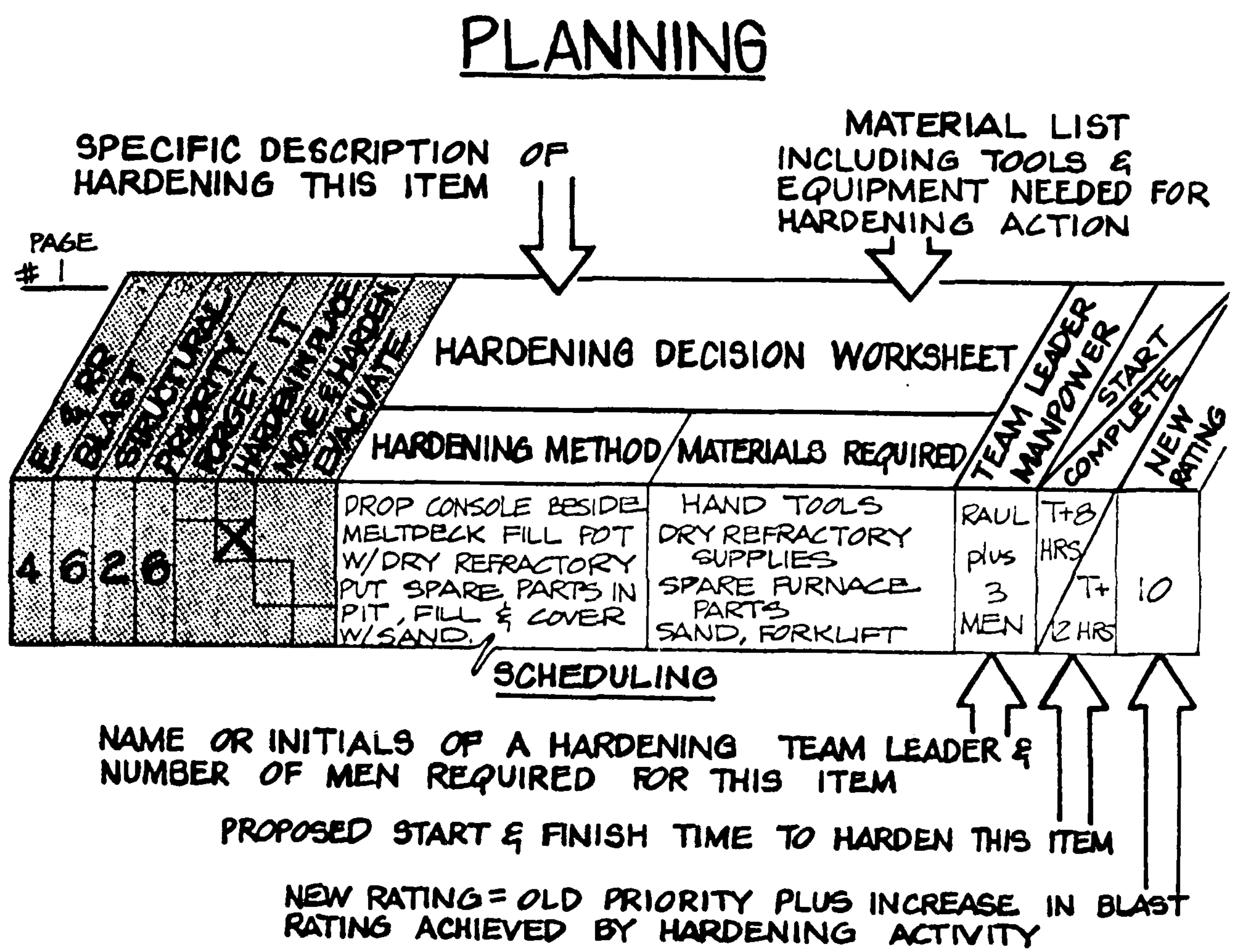

Figure 4. Hardening Decisions Format.

Booklet #4, Figure 1). Being very realistic, time allocated in any real situation will be different at different plants — and one might expect some kind of "normal" distribution curve to describe it. Incentives, natural disaster preparedness benefits, and sharpening perceptions of growing international tension could all affect this distribution and shift the curve toward increased allocation of time to prepare and harden. This subject is a promising one for future consideration. For the present, it is of interest to assess what might be accomplished with a minimum level of effort. In short, a defensible realistic minimum is very probably what was applied by in-plant personnel for this study. Thus, any effort leading to more advance planning and preparation by industry should result in even better outcomes than will be found here (in a later section).

Figure 5 (from Booklet #7 page 8) shows a completed analysis for some of the equipment at one plant. The change in vulnerability is the difference between the last column, entitled "New Rating", and the corresponding figure in the "Priority" column. Change in vulnerability is in one-to-one correspondence with the change in overpressure that will cause light-to-moderate damage.

PHASE II

Ground rules applied to the Phase II assessment were:

1. Conduct a complete hardening exercise at one plant;
2. Use a plant that participated in the Phase I effort;
3. Make both the Phase I and Phase II efforts of this participant entirely an in-plant exercise; i.e., without any input from SSI for either phase;
4. Document the hardening exercise photographically and without interfering with the hardening schedule.

EQUIPMENT INVENTORY WORKSHEET PAGE # ____

BLDG B

AREA FLOOR 5

SQUAD MEMBERS G. KAMBUROFF

ITEM NO	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR
1	AIR COMPRESSORS #1 AND #2 650 CFM WATER-COOLED 125 H.P. 240 V	2	H 6 FT W 5 FT L 8 FT DIA	ONE HORIZONTAL AND ONE VERTICAL CYLINDER IN L-SHAPED DESIGN 5/8" BOLTS TO FLOOR	0	2	2
2	AIR COMPRESSORS # 3, 4 AND 5. 155 CFM 40 H.P., 240 V WATER-COOLED	3	H 4 FT. W 4 FT. L 12 FT. DIA	HORIZONTAL SINGLE STAGE HEAVY CASTINGS BOLTED TO CONCRETE PAD WITH 1/2" BOLTS NARROW BASE	0	3	2
3	AIR RECEIVER/ PRESSURE TANK FOR PLANT AIR SUPPLY, TWO 5" AIR LINES, 1/2" DRAIN, TWO GAUGES	1	H 12 FT. W L DIA 5 FT.	ASME PRESSURE VESSEL WITH VERTICAL ORIENTATION BOLTED TO CONCRETE PAD WITH 4 1/2" BOLTS	0	3	3
4	MILLING MACHINE CINCINNATI MILACRON	1	H 6 FT W 4 FT L 6 FT DIA	VERTICAL MILL HEAVY CASTINGS BOLTED TO CONCRETE FLOOR WITH 3/8" BOLTS	0	2	3
5	AIR HOIST, PISTON-TYPE WIRE ROPE EQUIPPED 4,000 LBS	12	H W L 3 FT DIA 18 IN.	HUNG ON BRIDGE CRANES WITH ONE 7/8" BOLTS	0	3	3
6	AIR POLLUTION BAGHOUSE PULSE-AIR TYPE WITH 750 BAGS 16,000 CFM, 3 COMPARTMENTS	1	H 15 FT W 10 FT L 16 FT DIA	LIGHT GAUGE METAL WALLS, METAL STRUCTURE 3" x 3" x 1/4" ANGLE-IRON BOLTED TO CONCRETE PAD WITH 5/8" BOLTS AT 8 PLACES	0	4	4
7	ELECTRIC FURNACE 100 KW, 480 V 400 CYCLE	1	H 5 FT W 10 FT L 8 FT DIA 3 FT	POT ON TRUNNIONS HEAVY STEEL SHELL LINED WITH REFRACTORY CONTROL CONSOLE 4'x6'x3' STEEL DECK OVER 10' DEEP CONCRETE PIT	8 hours	2	2

DESCRIBE POSSIBLE COLLATERAL DAMAGE

METAL FRAMED BUILDING WITH 10% WINDOW AREA
METAL SIDING - NORTH WALL CONCRETE BLOCK
SEVERE MISSILE PROBLEMS WITH BOTH

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED.

PAGE # ____ HARDENING DECISION WORKSHEET

ITEM NO	A E+RR	B PLAST	C STRUCTURAL	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER & MANPOWER	START / COMPLETE	NEW RATING
1	4	5	2	6	#1		#2		#1 - TO RUN THROUGH CRISIS FOR SUPPORT #2 - MOVED TO TOWER OVEN PIT PROTECTED & COVERED	CANVAS OR PLASTIC COVER, HAND TOOLS, COME-ALONG, LARGE FORKLIFT, SAND	JIM C. 3 MEN	T+2 hrs / T+4 hrs	20
2	5	5	2	7	X				LEAVE RUNNING THROUGH CRISIS - SHUT DOWN BEFORE FINAL EVACUATION.	NONE	0	– / –	NO CHANGE
3	6	4	2	8		X			SHUT DOWN BEFORE FINAL EVACUATION AND FILL WITH WATER BRACE AND/OR GUY	HOIST CABLE, HAND TOOLS	1 MAN TONY	T+45 hrs / T+47 hrs	
4	5	5	2	7				X	REMOVE FROM PLANT - TAKE TO HOST AREAS AND STORE	LARGE FORKLIFT, FLATBED TRUCK	3 MEN JIM C.	T+4 hrs / T+6 hrs	HOST AREA
5	6	5	2	8			X		PUT INTO TOWER PITS PROTECT & COVER	SMALL FORKLIFT WITH MAN CAGE, HAND TOOLS	2 MEN DAVE GEO.	T+3 hrs / T+16 hrs	20
6	8	2	2	10	X				FORGET IT		0	– / –	NO CHANGE
7	4	4	2	6		X			DROP CONSOLE & TIE TO MELT DECK FILL POT WITH MOLDING REFRACTORY DRY & FILL PIT WITH SUPPLIES	HAND TOOLS ELECT. TAPE, HOIST CABLE, DRY REFRACTORY SUPPLIES, SAND FORKLIFT.	4 MEN PETE	T+8 hrs / T+16 hrs	16

← RATING →

PRIORITY = A+B or A+C (lowest sum)

Figure 5. Completed Worksheets for One Plant.

No requirement was placed on when the planning was to be done, excepting that it be done in advance so that hardening operations could begin immediately on the day of the exercise using in-plant personnel with no prior knowledge of what was to take place. Estimates for time, manpower, and materials expected to be expended on the hardening exercises were part of the Phase I output from the participants. In addition, information was collected on the level of effort actually spent in planning.

The outcome of the hardening exercise was measured in terms of how well the actual time, manpower, and resources expended compared with that estimated, and whether sufficient information was provided in the manual to preclude any glaring oversights in planning and executing the hardening.

Section 3
DISCUSSION OF RESEARCH ACCOMPLISHED

GENERAL

Fourteen plants contacted agreed to discuss industrial hardening, and ten of these participated to some degree in evaluating the manual. Thus, at least a partial evaluation of the manual was obtained at ten different kinds of plants. SSI conducted assessments in nine of these; at the tenth plant, a water utility, emergency planners went through all of the booklets as part of their normal assignment, but SSI personnel did not make an assessment.

Sufficient analytical assessments were completed in nine plants to calculate a vulnerability change. Of these nine plants, four agreed to have in-plant personnel go through an analytical assessment of one or more booklets. One of these plants was also assessed completely by someone from SSI who qualified as in-plant personnel — a former plant engineer from the participating plant. Among these four plants, three were fully analyzed by SSI and by in-plant personnel, enabling comparisons between assessments to be made.

For the Phase II effort; i.e., conducting hardening exercises, three plants agreed to participate: a wood products manufacturer, a precast concrete yard, and a small machine shop. By virtue of a well-planned move to minimize production loss, data were obtained at a fourth plant, indirectly.

Finally, comments were obtained from each participant regarding both general and specific aspects of an industrial hardening manual. These are presented with the data to help provide insight into the overall problem.

PHASE I — ANALYTICAL ASSESSMENTS

The participating plants comprised ten different industries: metal casting, electrical equipment manufacturing, metal stamping, steel fabrication, food processing, utility, wood products manufacturing, small job shop, electronic equipment manufacturing, and precast concrete construction. The last four in this series contributed to the Phase II study as well; they are discussed in detail later.

Table 1 summarizes what was undertaken at each plant (that is, booklets applied), both by SSI and by plant personnel. The Phase I studies for these plants are described in the following pages.

TABLE 1

BOOKLETS COMPLETED FOR HARDENING ANALYSIS AT PARTICIPATING INDUSTRIAL PLANTS

PLANTS / BOOKLET	PHASE I												PHASE II							
	METAL CASTING		ELECTRICAL EQUIPMENT MANUFACTURER		METAL STAMPING PLANT		STEEL FABRICATION		FOOD PROCESSOR		UTILITY		WOOD PRODUCTS MANUFACTURER		SMALL JOB SHOP		ELECTRONIC EQUIPMENT MANUFACTURER		PRECAST CONSTRUCTION	
	SSI	Plant	SSI	Plant	SSI	Plant	SSI	Plant	SSI	Plant	SSI	Plant	SSI	Plant	SSI	Plant	SSI	Plant	SSI	Plant
1	/////	✓	/////	MAYBE	/////	NONE	/////	MAYBE	/////	—	NONE	REVIEW & COMMENT	/////	NONE	/////	✓	/////	NONE	/////	✓
2	—	—	—		—		—		—	—			—		—	✓	—		—	✓
3	✓	✓	✓		—		—		—	—			—		✓	✓	✓		✓	✓
4	✓	✓	✓		✓		✓		—	—			✓		✓	✓	✓		✓	✓
5	✓	✓	✓		✓		✓		—	✓			✓		✓	✓	✓		✓	✓
6	✓	2 psi	✓		✓		✓		✓	—			✓		✓	2 psi	✓		✓	2 psi
7	✓	✓	✓		✓		✓		✓	✓			—		✓	✓	✓		✓	✓
9*													✓			✓				✓

///// Not applicable to SSI (see Figure 1, page 9)

✓ Booklet completed

— Booklet not attempted

* Applicable to Phase II only

Metal Casting Plant

This was a large caster of specialty items with well over two hundred employees and facilities that cover several acres. Analysis showed the vulnerability level raised from 2 psi to 5 psi by in-plant personnel and from 2 psi to 8 psi by SSI personnel. The difference was found in the vulnerability of a transformer vault, which housed transformers key to electric furnace operation. The vault, like most structures, had a blast vulnerability near 2 psi so that both the vault and the plant structure were rated at this figure without hardening. However, SSI personnel determined the transformer vault could be made to resist 8 psi by shoring and sandbagging to strengthen it. This option involves structural hardening, which had not been treated in booklet form in the manual yet, so was not available to the in-plant analyst. A booklet to cover this subject is now in process and will be added to the manual, soon, to eliminate this gap.

The following data sheets provide copies of the hardening worksheets developed for the plant by SSI and by in-plant personnel; these data collecting and planning efforts took approximately 48 hours and 60 hours respectively. Note in these data sheets that the lowest "Priority" before hardening was 5, while after hardening it was 11. A six-point change in the minimum hardening priority implies the vulnerability of the plant has been raised 6 psi (and vice versa). The estimated time and manpower for the hardening effort was 3 days, using 80%, 50% and 5% of plant personnel on successive days for the task. The hardening strategies applied were removal of key records to host areas, and hardening-in-place or move-and-harden equipment. Sand-casting pits provided excellent onsite resources for the latter.

Comments by personnel at this plant were very pertinent. The president

and general manager felt there would be little response by industrialists unless some clear-cut current benefit to industry were identified "up front". He suggested that a more practical incentive to planning than a hypothetical nuclear attack would need to be presented; perhaps, concern for interruption in power supplies by earthquake, fire, rolling blackouts, etc., could induce industry to implement emergency planning as a means to minimize potential loss from a local (or large-scale) disaster.

Another reviewer at this plant suggested that a note be added somewhere to indicate the person assigned to complete the booklet on equipment inventory and hardening priorities should be selected primarily for his capability to visualize alternative options for production, equipment function, etc., in order to make appropriate decisions about relative importance of plant equipment. Many other practical comments were made as well, which will be applied in the revised manual.

(Text continues on p. 31)

METAL CASTING PLANT

EQUIPMENT INVENTORY WORKSHEET # PAGE 1

BLDG MAIN BAY
AREA FRONT

SQUAD MEMBERS

ITEM No	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR
1	MOLD CORE OVEN WITH CAR ON RAILS	1	H 10' W 16' L 20' DIA	BRICK, BOX TYPE GAS FIRED	0	4	4
2	CUPOLAS COKE-FIRED, ON METAL LEGS BOLTED TO CONCRETE SLAB	2	H 60' W L DIA ≃ 60"	REFRACTORY LINED 1/2 REF BRICK INSIDE 1/2-IN. STEEL SHELL EXTENDS 20 FT ABOVE ROOF OF MAIN BAY	46 hrs IF OPERATING	2	2
3	ELECTRIC FURNACE, 325 KW, MELTING POT WITH INDUCTION COILS	1	H W L DIA ≃ 42"	ON 3-FT HIGH MEZZANINE (STEEL) POT MOUNTED ON PIVOTS FOR POURING LINED STEEL POT	8 hr	2	2
4	CONTROLS AND POWER CONDITIONING EQUIPMENT FOR 325 KW FURNACE	1	H 8' W 16' L 16' DIA	RELAYS, SWITCHES, METERS, LARGE CAPACITORS AND REACTORS INSIDE METAL CABINETS	2 hr	2	2
5	ELECTRIC FURNACE 1500KW MELTING POT WITH INDUCTION COILS	2	H 8' W L DIA 72"	LARGER VERSION OF ITEM 3 ABOVE. LINED STEEL POT	8 hr	2	2
6	CONTROL STATION ON MELT DECK FOR 1500 KW FURNACE	2	H 8' W 4' L 2' DIA	SAME AS ITEM 4 ABOVE WITHOUT CAPACITORS AND REACTOR	2 hr	2	2
7	TRANSFORMER VAULT WITH 2 EACH 1500 KW KV 1400V TRANSFORMERS 1 EACH 500 KVA TRANSFORMER AND CONTROLS, DISCONNECTS, CAPACITORS, REACTORS SPARE PARTS	1	H 25' W 25' L 40' DIA	CONCRETE BLOCK BLDG WITH REINFORCED CONCRETE ROOF AND FLOOR	2 hr	2	1

DESCRIBE POSSIBLE COLLATERAL DAMAGE

MAIN BAY FILLED WITH LADLES, FLASKS, MISC EQUIPMENT. TRANSFORMER VAULT IS BLOCK BLDG CLOSE TO ALL ELECTRIC FURNACES AND CONTAINS THEIR TRANSFORMERS AND SWITCHGEAR. COLLATERAL DAMAGE EVERYWHERE (FROM ALL SIDES)

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

PAGE 1 HARDENING DECISION WORKSHEET

ITEM No	E+RR (A)	BLAST (B)	STRUCTURAL (C)	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVALUATE	HARDENING METHOD	MATERIALS REQUIRED	[illegible]	[illegible]	NEW RATING
1	8	2	2	10	X				CAN BE JURY-RIGGED FROM SALVAGE.				
2	4	2	2	6		X			IF NEEDED POST ATTACK, CAN BE JURY-RIGGED FROM SALVAGE. FILL WITH SCRAP AND COKE OR SAND. TRUNCATE AND CUT LOOSE APC BAGHOUSE AND SPRAYS. HARDEN MATERIALS & EQUIPMENT TO REPAIR MISSILE DAMAGE.	RAIL CARTS, FORKS. ALL MATERIALS (COKE, ETC.) IN CHARGING ROOM	9	T+7 / T+13	
3	4	4	2	6		X			FURNACE FILLED WITH COMPONENTS AND SPARE PARTS FROM TRANSFORMER VAULT (IN SAND). PIT FILLED WITH SAME ≃ 100 CU FT	SHOVELS. HAND TOOLS	5	T+12 / T+24	14
4	4	2	2	6			X		DISCONNECT, BURY IN SAND PIT.	HAND TOOLS. HOIST CABLE.	3	T+12 / T+24	34
5	4	4	2	6		X			SAME AS ITEM 3 ABOVE. ≃ 800 CU FT OF PIT AVAILABLE FOR USE	SHOVELS, SCREWDRIVERS, CUTTERS, etc.	5	T+12 / T+24	14
6	4	2	2	6			X		SAME AS ITEM 4 ABOVE.	SAME AS ITEM 4 ABOVE	3	T+12 / T+24	34
7	3	2	2	5		X			SHORE ROOF SLAB. BERM OUTSIDE. SANDBAG INSIDE EQUIPMENT	TIMBERS, SAW, HAMMER, PAYLOADERS (2), HAND TOOLS (INSIDE), SHOVELS (4)	5	T+7 / T+15	11

RATING (columns A, B, C)

PRIORITY = A+B or A+C (lowest sum)

METAL CASTING PLANT

EQUIPMENT INVENTORY WORKSHEET # PAGE 2

BLDG MAIN BAY AND SIDE BAYS SQUAD MEMBERS

AREA REAR

ITEM NO	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR
1	ROLLOVER AND/OR JOLT/ SQUEEZERS HEAVY CASTIRON AND STEEL EQUIPMENT ALSO SQUEEZER/ ROLLOVER MACHINE	10	H ≈5' W ≈5' L ≈3' DIA	VERY HEAVY CONSTRUCTION AIR OPERATED BOLTED (3/4-IN. BOLTS) SECURELY TO LARGE CONCRETE MASS IN GROUND	0	3	3
2	CAR BOTTOM OVENS BOX TYPE REFRACTORY BRICK GAS-FIRED CORE CURING	8	H 10' W 12' L 16' DIA	BRICK ON CONCRETE PAD OLD AND IN POOR REPAIR ALONG BACK OF FOUNDRY BUILDING	0	3	4
3	CONTINUOUS MIXERS (SAND) AUGUR TYPE ON PEDESTAL 2 AUGURS IN TANDEM (CASCADED)	3	H 8' W 3' L 18'-30' DIA	HEAVY BASE BOLTED TO CONCRETE PAD STEEL TROUGHS ON LARGE BEARINGS ARTICULATED MIDWAY IN TROUGHS	0	3	3
4	AIR COMPRESSORS #1 AND #2 RECIPROCATING 125 hp 655 cfm @ 100 PSI TWO-STAGE WITH WATER COOLING	2	H 5' W 3' L 5' DIA	BOLTED (1/2-IN. BOLTS) TO CONCRETE BASES	NEED ONE TO OPERATE	2	2
5	AIR COMPRESSORS #3 #4 #5 40 hp 105 cfm @ 100 PSI HORIZONTAL	3	H 5' W 3' L 10' DIA	SINGLE-STAGE HORIZONTAL RECIPROCATING WITH LARGE FLYWHEELS BOLTED (5/8-IN BOLTS) TO HEAVY PAD	0	3	2
6	SWING GRINDERS/ CUTOFF SAWS, SUSPENDED FROM HOIST BELT DRIVEN FROM 40 hp MOTOR IN FRAME PORTABLES	6	H 3' W 2' L 10' DIA		0	3	3
7	SPECTROGRAPH (LAB)	2 parts	H 8' W L DIA	TYPICAL CONTROL PANEL ENCLOSURE CONTAINS 4'X1'X3' CASTIRON/STEEL VACUUM CHAMBER & ELECTRONICS (SENSITIVE) 1 PANEL W/VACUUM, 1 PANEL W/CONTROLS, READOUT	0	3	1

DESCRIBE POSSIBLE COLLATERAL DAMAGE

IT'S EVERYWHERE!

SUGGEST REMOVING OR BURYING EQUIPMENT

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

PAGE 2 HARDENING DECISION WORKSHEET

ITEM NO	E+RR (A)	BLAST (B)	STRUCTURAL (C)	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	[illegible]	START/COMPLETE	NEXT MEETING
1	6	6	2	8		X			LOWER CENTER OF GRAVITY SANDBAG OR BERM	30 SANDBAGS PER MACHINE (OR 1 1/2 YDS SAND)	9	T+7 / T+12	16
2	7	2	2	9		X			JURY-RIGGED FROM SALVAGE FILL TWO WITH THE BAGGED MOLDING SUPPLIES LEAVE OTHERS	FORKLIFT AND DRIVER	3	T+7 / T+12	
3	6	3	2	8			X		DISASSEMBLE AT MAIN BEARINGS, LAY IN MOLDING PITS, STRIP PEDESTAL AND BURY ALSO, SANDBAG OR BERM PEDESTAL FRAME	HAND TOOLS JIB CRANE PLASTIC WRAPPING 1 YD SAND	4	T+7 / T+12	25
4	4	6	2	6			X		REMOVE #2 AND BURY IN MOLDING PIT LEAVE #1 OPERATING/EXPENDABLE	HAND TOOLS LARGE FORKLIFT	3	T+12 / T+16	25 ON #2
5	5	6	2	7			X		BLOCK TO REINFORCED CONCRETE WALLS; SHORE ROOF SLAB, SANDBAG MOTORS, FILL ACCUMULATORS WITH WATER	HAND TOOLS SANDBAGS TIMBERS, SHOVELS	5	T+8 / T+12	15
6	6	3	2	8			X		BURY IN MOLDING PIT	RAIL CART AND FORKLIFT		T+10 / T+12	36
7	4	2	2	6			X		MOVE TO SAND BIN STACK STEEL FLASKS AROUND IT COVER IT WITH 2" COMPRESSIBLE MATERIAL THEN 2 FT OF SAND	FORKLIFT HAND TOOLS SHOVELS OR PAYLOADER FOR COVERING WITH SAND	4	T+7 / T+10	14

← RATING →

PRIORITY = A+B or A+C (lowest sum)

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METAL CASTING PLANT

EQUIPMENT INVENTORY WORKSHEET PAGE # 1

BLDG MAIN BAY
AREA FRONT
SQUAD MEMBERS

ITEM NO	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	B	RR
1	MOLD CORE OVEN WITH CAR ON RAILS	1	H 10' W 16' L 20' DIA	BRICK, BOX TYPE GAS FIRED	0	4	4
2	CUPOLAS, COKE FIRED, ON METAL LEGS BOLTED TO CONCRETE SLAB	2	H 60' W L DIA ≈ 60"	REFRACTORY LINED ½ REF. BRICK INSIDE ½-IN. STEEL SHELL EXTENDS 20 FT ABOVE ROOF OF MAIN BAY	4-6 hrs IF OPERATING	2	2
3	ELECTRIC FURNACE, 325 KW. MELTING POT WITH INDUCTION COILS	1	H W L DIA ≈ 42"	ON 5-FT HIGH MEZZANINE (STEEL) POT MOUNTED ON PIVOTS FOR POURING LINED STEEL POT (SEE BACK FOR SKETCH)	8 hrs	2	2
4	CONTROLS AND POWER CONDITIONING EQUIPMENT FOR 325 KW FURNACE	1	H 8' W 16' L 16' DIA	RELAYS, SWITCHES, METERS, LARGE CAPACITORS AND REACTORS INSIDE METAL CABINETS (SEE BACK FOR SKETCH)	2 hr	2	2
5	ELECTRICAL FURNACE 1500 KW MELTING POT WITH INDUCTION COILS	2	H 8' W L DIA 72"	LARGER VERSION OF ITEM 3 ABOVE LINED STEEL POT (SEE SKETCH)	8 hr	2	2
6	CONTROL STATION ON MELT DECK FOR 1500 KW FURNACE	2	H 8' W 4' L 2' DIA	SAME AS ITEM 4 ABOVE WITHOUT CAPACITORS AND REACTORS (SEE SKETCH)	2 hr	2	2
7	TRANSFORMER VAULT WITH 2 EACH 1500 KVA 14 KV-1400 V TRANSFORMERS 1 EACH 500 KVA TRANSFORMER & CONTROLS, DISCONNECTS, CAPACITORS, REACTORS, SPARE PARTS	1	H 25' W 25' L 40' DIA	CONCRETE BLOCK BLDG WITH REINFORCED CONCRETE ROOF AND FLOOR	2 hr	2	1

DESCRIBE POSSIBLE COLLATERAL DAMAGE
MAIN BAY FILLED WITH LADLES, FLASKS, MISC. EQUIPMENT. TRANSFORMER VAULT IS BLOCK BLDG CLOSE TO ALL ELECTRIC FURNACES AND CONTAINS THEIR TRANSFORMERS AND SWITCHGEAR. COLLATERAL DAMAGE EVERYWHERE (FROM ALL SIDES)

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

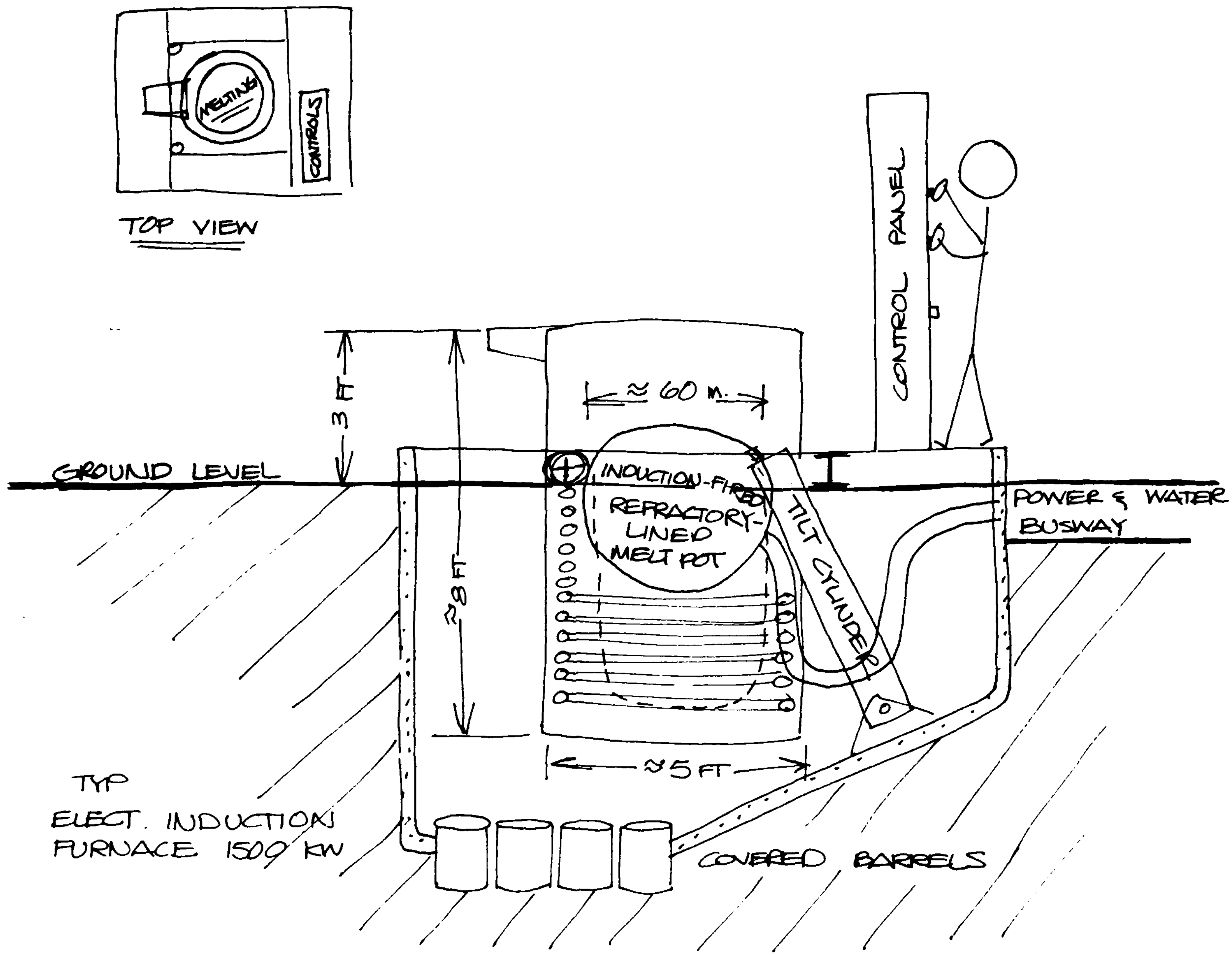
PAGE # 1 HARDENING DECISION WORKSHEET

E+RR (A)	BLAST (B)	STRUCTURAL (C)	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER MANPOWER	START / COMPLETE	NEW RATING
8	2	2	10	X				KNOCK DOWN IF TIME PERMITS	INTERNATIONAL H-25 PAYLOADERS, SLEDGE HAMMERS	TONY + 3	hr 50 / ?	?
4	2	2	6		X			FILL WITH SCRAP AND COKE OR SAND TRUNCATE AND CUT LOOSE AIR BAGHOUSE AND SPRAYS	RAIL CARTS, FORKS, ALL MATERIAL (COKE, ETC.) IN CHARGING ROOM	TONY + 2 GEORGE + 6	hr 30 / hr 36	≈10
4	4	2	6/8		X			FURNACE FILLED WITH COMPONENTS & SPARE PARTS FROM TRANSFORMER VAULT (IN SAND) PIT FILLED WITH SAND ≈ 120 CU FT	SHOVELS HAND TOOLS	ANGELO + 2 GEOFF + 1	hr 22 / hr 33	≈12
4	2	2	6			X		WIRES REMOVED FROM TERMINAL STRIPS, PANEL LAID DOWN BESIDE MELT DECK AND TIED WITH WIRE ROPE	HAND TOOLS HOIST CABLE AND CLAMPS (1'×12'×8' AND 2'×12'×8'—@ EACH) NAILS	JOE + 2	hr 22 / hr 33	≈10
4	4	2	6/8		X			SAME AS ITEM 3 ABOVE ≈800 CU FT OF POT AVAILABLE FOR USE	SHOVELS SCREWDRIVERS CUTTERS, etc.	ANGELO + 2 DANIEL + 1	hr 22 / hr 33	≈12
4	2	2	6			X		SAME AS ITEM 4 ABOVE	SAME AS ITEM 4 ABOVE	SAM + 2	hr 22 / hr 32	≈10
3	2	2	5		X			BERM OUTSIDE SANDBAG INSIDE EQUIPMENT	PAYLOADERS (2) HAND TOOLS (INSIDE) SHOVELS (4)	MIGHEL 4 OUTSIDE 3 INSIDE	hr 35 / hr 40	≈8

RATING (A, B, C)

PRIORITY = A+B or A+C (lowest sum)

Back of Equipment Inventory Worksheet Page 1



METAL CASTING PLANT

EQUIPMENT INVENTORY WORKSHEET # PAGE 2

BLDG MAIN BAY AND SIDE FLOORS SQUAD MEMBERS

AREA REAR

ITEM NO.	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR
1	ROLLOVER AND/OR JOLT SQUEEZERS HEAVY CASTIRON AND STEEL EQUIPMENT ALSO SQUEEZER/ ROLLOVER MACHINE	18	H ≃ 5' W ≃ 5' L ≃ 3' DIA	VERY HEAVY CONSTRUCTION AIR OPERATED, BOLTED (3/4-IN. BOLTS) SECURELY TO LARGE CONCRETE MASS IN GROUND SEE BACK FOR SKETCH	0	3	3
2	CAR BOTTOM OVENS, BOX-TYPE REFRACTORY BRICK GAS-FIRED CORE CURING	8	H 10' W 12' L 16' DIA	BRICK ON CONCRETE PAD. OLD AND IN POOR REPAIR ALONG BACK OF FOUNDRY BLDGS	0	3	4
3	CONTINUOUS MIXERS (SAND) AUGUR TYPE ON PEDESTAL 2 AUGURS IN TANDEM (CASCADED)	3	H 8' W 3' L 18-30' DIA	HEAVY BASE BOLTED TO CONCRETE PAD STEEL TROUGHS ON LARGE BEARINGS ARTICULATED MIDWAY IN TROUGHS	0	3	3
4	AIR COMPRESSORS #1 AND #2 RECIPROCATING 125 hp 655 cfm @ 100 PSI TWO-STAGE WITH WATER COOLING	2	H 5' W 3' L 5' DIA	BOLTED (1/2-IN. BOLTS) TO CONCRETE BASES	ONE ALMOST LAST / SAVE	2	2
5	AIR COMPRESSORS #3, #4, #5 40 hp 165 cfm @ 100 PSI HORIZONTAL	3	H 5' W 3' L 10' DIA	SINGLE-STAGE HORIZONTAL RECIPROCATING WITH LARGE FLYWHEELS BOLTED (5/8-IN. BOLTS) TO HEAVY PAD	SAVE TO DEAD LAST	3	2
6	SWING GRINDERS/ CUTOFF SAWS SUSPENDED FROM HOIST, BELT DRIVEN FROM 40 hp MOTOR ON FRAME PORTABLE	6	H 3' W 2' L 10' DIA		0	3	3
7	SPECTROGRAPH (LAB)	2 BARS	H 8' W L DIA	TYPICAL CONTROL PANEL ENCLOSURE CONTAINS 4'x1'x3' CASTIRON/STEEL VACUUM CHAMBER & ELECTRONICS (SENSITIVE) 1 PANEL W/VACUUM, 1 PANEL W/CONTROLS, READOUT	0	3	1

DESCRIBE POSSIBLE COLLATERAL DAMAGE

IT'S EVERYWHERE!

SUGGEST REMOVING OR BURYING EQUIPMENT

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

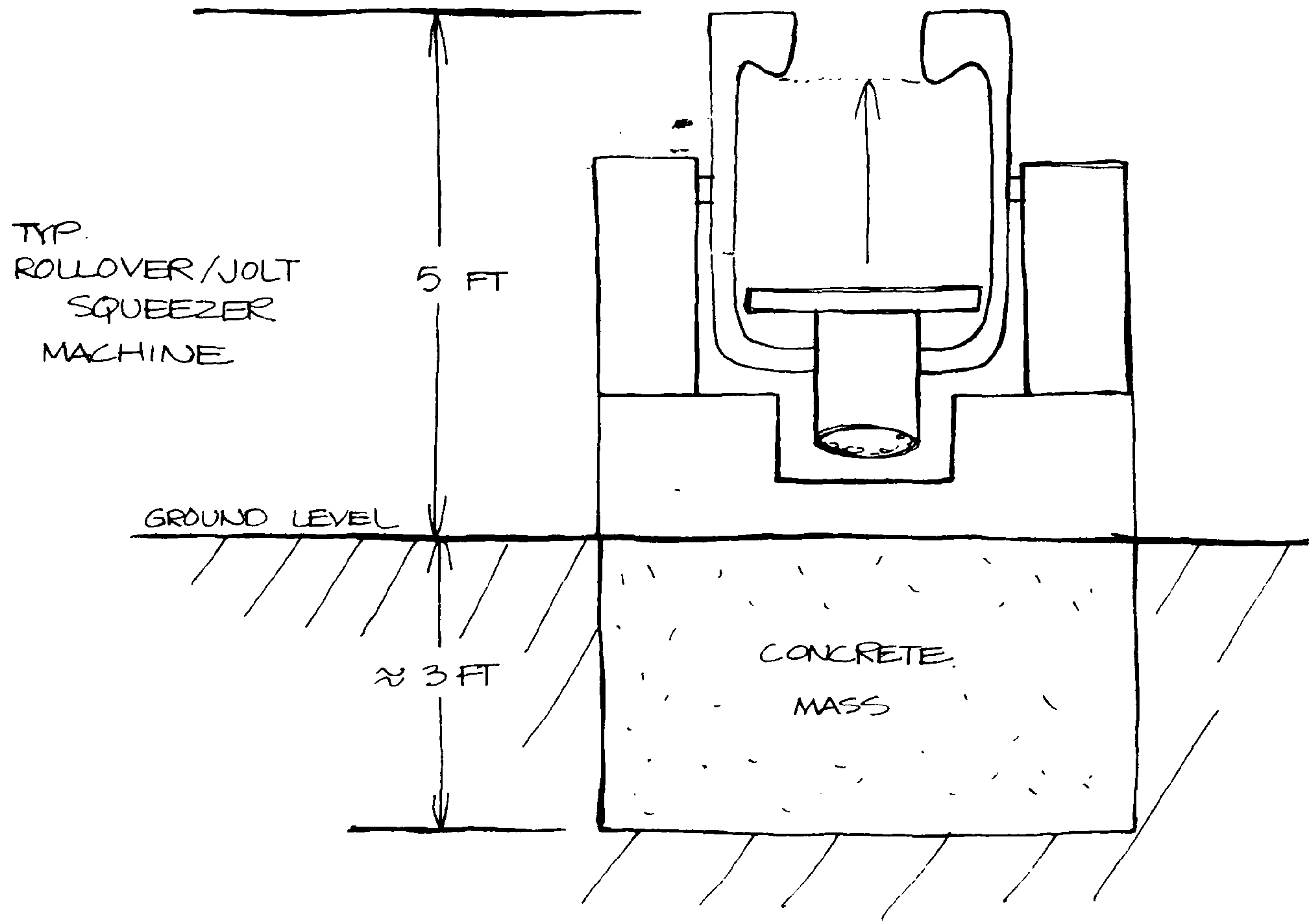
PAGE # 2 HARDENING DECISION WORKSHEET

ITEM NO.	E+RR (A)	BLAST (B)	STRUCTURAL (C)	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER MANPOWER	START	COMPLETE	NEW RATING
1	6	6	2	8		X			LOWER CENTER OF GRAVITY SANDBAG OR BERM	30 SANDBAGS PER MACHINE (OR 1½ YDS SAND)	FRED + 8	hr 28	hr 32	≥10
2	7	2	2	9		X			FILL TWO WITH THE BAGGED MOLDING SUPPLIES LEAVE OTHERS	FORKLIFT AND DRIVER	WAREHOUSE MAN + 2	hr 0	hr 14	≥11
3	6	3	2	8			X		DISASSEMBLE AT MAIN BEARINGS LAY IN MOLDING PITS STRIP PEDESTAL AND BURY ALSO SANDBAG OR BERM PEDESTAL FRAME	HAND TOOLS, JIB CRANE, PLASTIC WRAPPING 1 YD SAND	PAUL + 3	hr 22	hr 27	12+
4	4	6	2	6			X		REMOVE #2 AND BURY IN MOLDING PIT. LEAVE #1 OPERATING	HAND TOOLS LARGE FORKLIFT	PAUL + 2	hr 48	hr 51	12+
5	5	6	2	7			X		BURY ONE IF TIME PERMITS LEAVE OTHERS, OR SANDBAG IN PLACE	HAND TOOLS SANDBAGS SHOVELS	PAUL + 2	hr 51	hr 53	12+
6	6	3	2	8			X		BURY IN MOLDING PIT	RAIL CART AND FORKLIFT TO TAKE TO BURY	CLEAN ROOM +1 FORK +2 MEN	day 1 hr 12	hr 14	12+
7	4	2	2	6			X		REMOVE AND LAY IN SAND BIN AND COVER	FORKLIFT HAND TOOLS SHOVELS OR PAYLOADER FOR COVERING WITH SAND	LARRY + 3	day 2 hr 2	day 2 hr 2	≥10

← RATING →

PRIORITY = A+B or A+C (lowest sum)

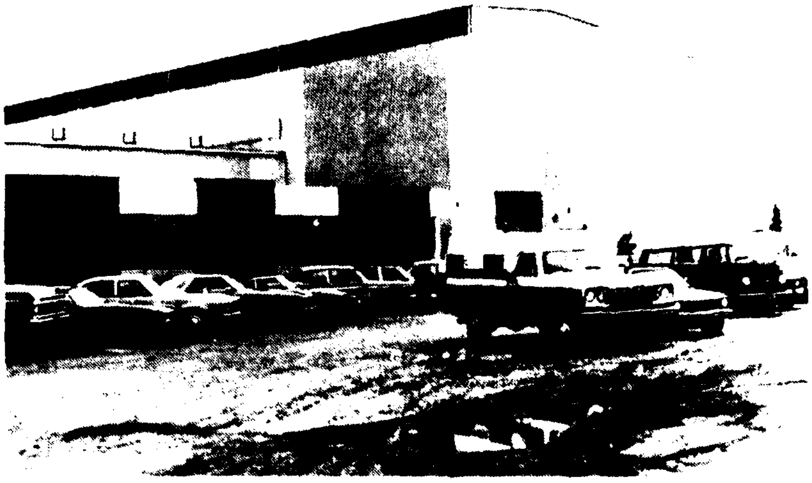
Back Of Inventory Worksheet Page 2



Electrical Equipment Manufacturer

This plant is a producer of large utility transformers with over two hundred employees and over two acres of floor space. Figures 6 through 9 provide some idea of plant size and characteristic operations. Following these figures are copies of the hardening worksheets developed for this plant by SSI personnel. This planning effort took approximately 30 hours. On these data sheets, the lowest "Priority" before hardening was 6, and the lowest "New Rating" after hardening was 20+ corresponding to a minimum change of 14+ psi. A review of these 20+ ratings set the minimum improvement at 18 psi for this plant. The hardening was estimated to be completed by the end of day two. (In all the SSI analyses it was assumed three shifts would operate each day.) In the discussion with the plant engineer, he was asked what the absolute minimum equipment would be to enable the plant to return to a minimum level of production. After much thought and discussion he decided a low level could be achieved with just a cutting torch, welder, generator, fuel, and the raw materials salvaged.

(Text continues on p. 47)

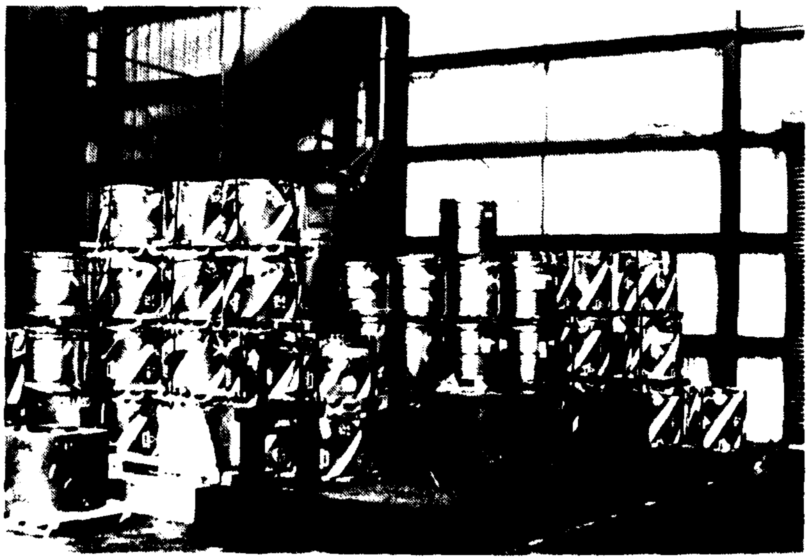


A. Photograph of Facility

B. Cooling Fin Fabrication

Fig. 6. Electrical Equipment Manufacturer.

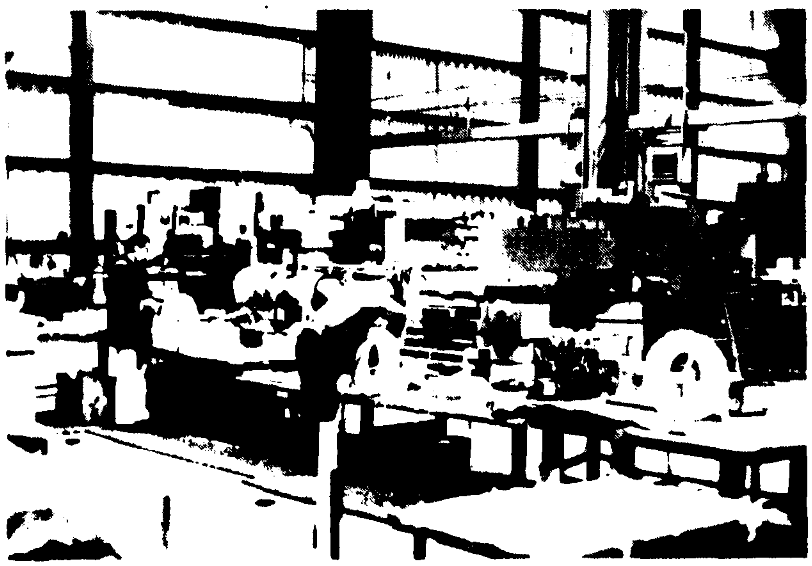
A. Wire Stock



B. Sheet Steel Coils

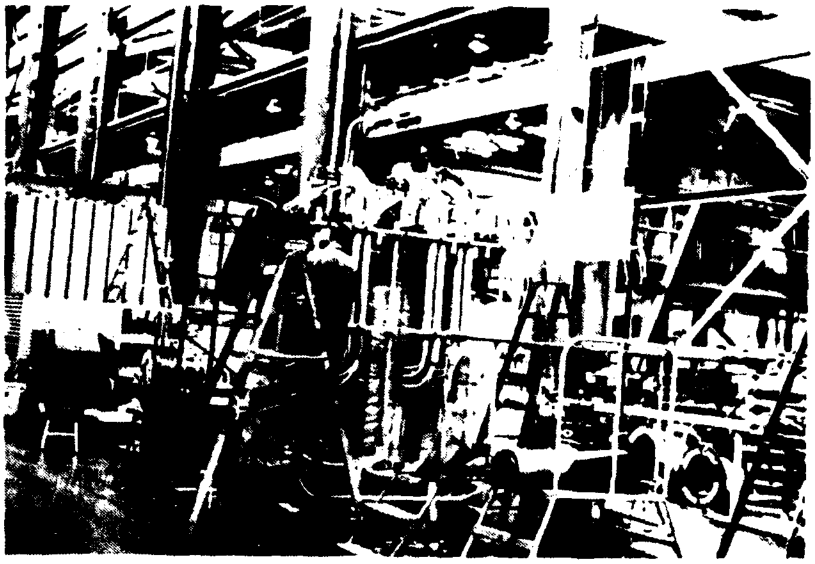
Fig. 7. Electrical Equipment Manufacturer.

A. View of Main Corridor in Plant



B. Coil Fabrication Area

Fig. 8. Electrical Equipment Manufacturer.



A. Core Assembly

B. Completed Core

Fig. 9. Electrical Equipment Manufacturer.

ELECTRICAL EQUIPMENT MANUFACTURER

EQUIPMENT INVENTORY WORKSHEET PAGE # 1 — PAGE # 1 HARDENING DECISION WORKSHEET

BLDG 1
AREA BAY 1
SQUAD MEMBERS

ITEM NO	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR	E+RR A	BLAST B	STRUCTURAL C	PRIORITY	FORGET IT / HARDEN IN PLACE / MOVE AND HARDEN / EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM	MANHOURS / START COMPLETE	NEW RATING
1	PUNCH PRESS	2	H — W — L GROUP 2 DIA —	VERTICAL WITHOUT MOUNTS VERTICAL WITH 5/8" BOLTS AGAINST METAL WALL OF BLDG	0	3	3	6	4	2	8	X	PUT INTO SAND BLAST PIT BAY 2 (2 EACH ITEMS)	FORKLIFT HAND TOOLS HOIST OVER PIT	HARRY + 3	0 / +3	25+
2	LATHES	4	H 4' W 4' L 12' DIA —	5/8" BOLTS AGAINST METAL WALLS	0	3	3	6	5	2	8	X	PUT INTO SAND BLAST PIT, BAY 2 (2 EACH ITEMS)	FORKLIFT HAND TOOLS HOIST OVER PIT	HARRY + 3	+2 / +6	25+
3	HERTZ MILL (CINCINNATI)	1	H 4' W 2' L 6' DIA —	TWO 3/8" BOLTS AGAINST METAL WALLS	0	3	2	5	4	2	7	X	PUT INTO SAND BLAST PIT, BAY 2 (2 EACH ITEMS)	FORKLIFT HAND TOOLS HOIST OVER PIT	PETE + 2		25
4	VERTICAL MILL (BRIDGE)	1	H 8' W 2' L 5' DIA —	TWO 3/8" BOLTS	0	3	2	5	4	2	7	X	PUT INTO SAND BLAST PIT, BAY 2 (2 EACH ITEMS)	FORKLIFT HAND TOOLS HOIST OVER PIT	PETE + 2		25
5	DRILL PRESS ONE GANGED (4 x 4 x 8) ONE SINGLE (3 x 4 x 8)	2	H — W — L — DIA —	NO BOLTS TO FLOOR FOR GANGED PRESS TWO BOLTS (3/8") FOR SINGLE	0	3	3	6	4	2	8	X	COIL WINDING PIT (BAY 6) (2 EACH)	FORKLIFT HAND TOOLS HOIST OVER PIT	PETE + 2		25
6	DOALL HACKSAW	1	H 3' W 6' L 3' DIA —	TWO 3/8" BOLTS HORIZONTAL CONFIGURATION	0	3	4	7	2	2	9	X	PUT IN TRANSFORMER CAGE LAY IN LOADING DOCK (INTERIOR)	HAND TOOLS FORKLIFT	PETE + 2		25+
7			H — W — L — DIA —														

DESCRIBE POSSIBLE COLLATERAL DAMAGE
ALL EQUIPMENT NEAR/AGAINST METAL WALL

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

← RATING → (columns A, B, C)

PRIORITY = A+B or A+C (lowest sum)

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ELECTRICAL EQUIPMENT MANUFACTURER

EQUIPMENT INVENTORY WORKSHEET PAGE # 2

BLDG 1
AREA BAY 1
SQUAD MEMBERS

LINE NO.	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR
1	PARTITIONS PORTABLE, CORRUGATED ALUMINUM	5	H 7' W 10' L DIA	SURROUND SIX WELDING STATIONS WITH MANUAL WELDERS	0	4	4
2	PARTITIONS-METAL STAND ALONE ON 6" X 24" FEET (2)	7	H 7' W 12' L 1/16" thick DIA	BETWEEN WELDING STATIONS 15' FROM METAL WALL OF PAINT SHOP	0	4	4
3	WELDING TABLES APPROX 6X7 FT APPROX 4X5 FT	7	H W L DIA	TOP 1/2" TO 1" THICK WELDED TO HEAVY SUPPORTS	0	3	4
4	WELDERS - ELECTRIC ARC	7	H 2½' W 3' L 4' DIA	PORTABLE, PLUG-IN	0	2	3
5	GAS WELDING RIGS	3	H W L DIA	ACETYLENE WELDERS WITHOUT CARTS	0	2	2
6	PUNCH PRESS ONE No. 1/2 ONE No. 2½	2	H 3' W 5' L 7' DIA	EACH WITH FOUR 5/8" BOLTS AGAINST WEST WALL (METAL)	0	3	2
7	THREADING MACHINE (OSTER)	1	H 2' W 4' L 4' DIA	AGAINST WEST METAL WALL NOT FASTENED DOWN	0	3	3

DESCRIBE POSSIBLE COLLATERAL DAMAGE

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

PAGE # 2 **HARDENING DECISION WORKSHEET**

LINE NO.	E+RR (A)	BLAST (B)	STRUCTURAL (C)	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER MANPOWER	START COMPLETE	NEW RATING
1	8	2	2	10			X		USE FOR COVERING BERMED LOADING AREA FILLED WITH SUPPLIES	NONE ONE FORKLIFT			25+
2	8	2	2	10			X		USE TO COVER PERFORATED FLOOR IN SAND BLAST CABINETS	ONE FORKLIFT			25+
3	7	10	2	9	X				PROTECTIVE HOUSEKEEPING; INVERT OUTSIDE	ONE FORKLIFT			25+
4	5	4	2	7			X		STORE IN TRANSFORMER CASE FOR BLAST AND EMP PROTECTION LODGE CASE IN INSIDE DOCK	CRANE (Bridge) TO MOVE TRANSFORMER CASE INITIALLY THEN NONE			25
5	4	10	2	6			X		LOWER INTO WINDING PIT AND FILL SPACES IN SAND BLAST PIT	FORKLIFT TO HANDLE BOTTLES			20
6	5	4	2	7			X		STORE IN SAND BLAST PIT, BAY 3 (2 ITEMS)	HOIST, FORKLIFT			25
7	6	6	2	8			X		STORE IN SAND BLAST PIT. BAY 3 (2 ITEMS)	HOIST, FORKLIFT			25

← RATING →

PRIORITY = A+B or A+C (lowest sum)

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ELECTRICAL EQUIPMENT MANUFACTURER

EQUIPMENT INVENTORY WORKSHEET # PAGE 3 — # PAGE 3 **HARDENING DECISION WORKSHEET**

BLDG 1

AREA BAY 1 (AGAINST WEST (METAL) WALL

SQUAD MEMBERS

ITEM NO	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	EL	RR	E+RR A	BLAST B	STRUCTURAL C	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER MANPOWER	START COMPLETE	NEW RATING
1	PAINT BOOTH FLAMMABLES	1	H 20' W 60' L 20' DIA	METAL POLES 15 FT. APART FRAMED WITH SHEET METAL WALLS EQUIPPED WITH ELECTRIC HOIST & CHAIN CONVEYOR ON ROLLERS	0	3	3	6	2	2	8	X				REMOVE OR COVER FLAMMABLES (PROTECTIVE HOUSEKEEPING)				26
2	SHEET METAL AND GLASS OFFICE STORAGE AREA ON TOP FOR BOXES	1	H 8' W 15' L 15' DIA	3/8" BOLT IN EACH CORNER BOLTED TOGETHER CROSS TIES AND TURNBUCKLES	0	4	4	8	2	2	10	X				N/A	N/A	NONE		
3	JIB CRANES (1/2- AND 1-TON CAPACITY) ELECTRIC HOISTS 20 FT JIBS ABOVE LATHES, MILLS, AND WELDING MACHINES	10	H W L DIA	3 AGAINST WEST WALL 7 ON COLUMNS OPPOSITE SIDE BAY	0	3	2	5	6	2	7			X		REMOVE CABLES FROM SOME FOR TIES STOW HOISTS IN SAND BLAST PIT BAY 3	LADDER HAND TOOLS			25
4	BUSWAY 160 LINEAR FT 440 V WITH DISCONNECTS (40) 160 FT WEST WALL, 160 FT BETWEEN BAYS	2	H W L DIA	AGAINST WEST WALL ON TOP ≃ 12 FT HIGH ALSO ON COLUMN ROW # 1	LAST	2	3	5	4	2	7	X				REPLACE				
5	ELECTRIC HEATERS (COMFORT) UP BY BUSWAYS	13	H 2' W 3' L 3' DIA	HANG UNDER BUSES	0	4	3	7	4	2	9	X				NOT NECESSARY FOR PRODUCTION				25+
6			H W L DIA																	
7			H W L DIA																	

DESCRIBE POSSIBLE COLLATERAL DAMAGE

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

← RATING →

PRIORITY = A+B or A+C (lowest sum)

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ELECTRICAL EQUIPMENT MANUFACTURER

EQUIPMENT INVENTORY WORKSHEET # PAGE 4

HARDENING DECISION WORKSHEET # PAGE 4

BLDG. 1

AREA BAY 2

SQUAD MEMBERS

ITEM NO	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR	E+RR	BLAST	STRUCTURAL	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER	MANPOWER	START COMPLETE	NEW RATING
1	SAND BLAST ROOM PANGBORN OVER PIT	1	H 20' W 20' L 30' DIA	WELDED TOGETHER, 5 FT CENTERS FOR PANELS SHEET METAL SIDES APPROX 1/8 IN OVER FULL SIZED PIT	0	3	3	6	2	2	8		X			CUT DOWN HOPPERS UNDER PERFORATED FLOOR. CUT AND PROP SIDEWALLS WELD "U" CHANNEL ACROSS SPAN	CUTTING TORCHES, WELDERS, HAND TOOLS, U CHANNELS WELDED TO 20 FT LENGTHS				25+
2	PRESSURE VESSELS FOR SAND BLASTER	2	H 6' W L DIA 3'	ONE AIR ACCUMULATOR ONE PRESSURE VESSEL FOR SHOT	0	3	2	5	10	2	7			X		LAY ON TOP OF ITEMS IN SAND BLAST PIT (2 ITEMS)	CUTTING TORCHES				20
3	GAS CUTTING RIG AND TABLE 5x12 WITH FOUR CUTTING TIPS	1	H W L DIA	HEAVY BASE BOLTED DOWN (5/8" BOLTS) ON EACH CORNER	0	3	3	6	10	2	8			X		USE UNTIL LAST FILL IN OPEN SPOTS IN PITS WITH BOTTLES	ROPE				25+
4	WELDING TABLES DIFFERENT SIZES 6 FT x 6 FT HEAVY BASE	3	H W L DIA	TWO 5/8" BOLTS	0	3	4	7	9	2	9	X				PROTECTIVE HOUSEKEEPING PROBLEM TAKE OUT AND INVERT	FORKLIFT				25+
5	ARC WELDER, ELECTRIC, TYP. LINCOLN	13	H 4' W 3' L 3' DIA	ALONG BAY 2 PORTABLE	0	2	3	5	4	2	7			X		PUT IN TRANSFORMER CASE, STORE IN INTERIOR DOCK	FORKLIFT TO MOVE STORAGE				20+
6	CABINETS MATERIAL	1	H 8' W 2' L 12' DIA	MOBILE, ON SKID COLUMN LINE BETWEEN BAY 1 AND BAY 2	0	4	4	8	3	2	10	X				PROTECTIVE HOUSEKEEPING PROBLEM LAY DOWN AND LEAVE	NONE				25+
7			H W L DIA																		

DESCRIBE POSSIBLE COLLATERAL DAMAGE

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

← RATING →

PRIORITY = A+B or A+C (lowest sum)

ELECTRICAL EQUIPMENT MANUFACTURER

EQUIPMENT INVENTORY WORKSHEET PAGE # 5 — **HARDENING DECISION WORKSHEET** PAGE # 5

BLDG 1
AREA BAY 2
SQUAD MEMBERS

ITEM NO	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR	E+RR (A)	BLAST (B)	STRUCTURAL (C)	PRIORITY	FORGET IT	PROTECT IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER MAN-HOURS	START / COMPLETE	NEW RATING
1	BRIDGE CRANE (ELECTRIC) 10/35 TON PENDANT CONTROL 50 FT SPAN ELECTRIC	1	H W L DIA	BUS-FED ELECTRIC APPROX 25 FT. HIGH ON RAILS	0	2	2	4	6	2	6		X			MOVE TO SAND BLAST CABINET GUY AND BRACE OVER PIT	WELDERS HOIST CABLE HAND TOOLS			20+
2	GAS WELDING RIG ACETYLENE, NO DOLLIES	6	H W L DIA	BOTTLES CHAINED TO POST	0	2	2	4	10	2	6			X		PUT INTO AVAILABLE SPACE REGULATORS IN TRANSFORMER CASE	FORKLIFT, ROPE			20+
3	TANK, OIL STORAGE (ON SIDE)	1	H W L 12' DIA 10'	UNDER MEZZANINE FOR ELECTRIC LOAD CENTER 20' X 15' X 12'	0	4	4	8	3	2	10	X				DRAIN OIL FILL WITH WATER				25+
4	LOAD CENTER #3 SUBSTATION	1	H 3' W 8' L 15' DIA	ON MEZZANINE OVER OIL TANK. 11,400 V; 101 AMPS TRANSFORMER WITH SWITCHGEAR	0	2	2	4	2	2	6			X		DISCONNECT LAST LOWER DOWN AND PUT INTO TRANSFORMER CASE IN DOCK	2 FORKLIFTS HAND TOOLS CUTTING TORCHES			20+
5	JIB CRANES ½-AND 1-TON CAPACITY (SEE ITEM 3, PAGE 3)	6	H W L DIA	MAY BE EASILY REMOVED FROM JIB	0	3	2	5	6	2	7			X		REMOVE HOISTS LOWER INTO OPEN SPACES IN SAND BLAST PITS	LADDERS HAND TOOLS			20+
6	BUSWAYS (440 V) BOTH SIDES OF BAY STRUNG BETWEEN COLUMNS 160 LINEAR FT EACH SIDE	2	H W L DIA		0	2	3	5	4	2	7	X				REPLACE				
7	COIL WINDING MACHINE ON WHEELS SIZE OF LATHE APPROX 3' X 4' X 8'	8	H W L DIA	IN BAYS 5 THROUGH 8 LIGHT METAL ON WELDED FRAME WITH CONTROLLABLE MOTOR	0	3	3	6	3	2	8			X		PARTIALLY DISASSEMBLE LOAD INTO TRANSFORMER CASES IN DOCK (4 IN DOCK)	HAND TOOLS ONLY			25+

DESCRIBE POSSIBLE COLLATERAL DAMAGE

← RATING →

PRIORITY = A+B or A+C (lowest sum)

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION IF DESIRED

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Metal Stamping

This producer of large metal stampings is one of the largest such companies in the West, with well over 100 employees. There was no in-plant analysis here, in part because the plant is located only a few hundred feet from a tank farm storing over half a million gallons of flammables. Though this would be a factor in an actual hardening situation, it was of little concern in testing the manual for application to similar plants not so situated.

The SSI data collection and planning efforts at this plant took about 22 hours (copies of the SSI completed worksheets follow). The SSI analysis showed the vulnerability level (excluding the tank farm) could be raised 14 points, or from 2 psi to 16 psi, and could be completed at the end of the first day. The hardening methods applied in the analysis were removal of some items to host areas, and gang anchoring and cross brace welding used to provide stability and mutual protection for the very heavy stamping machines. These machines are very tall, tremendously massive, small-based units that would otherwise lack stability and likely be damaged by overturning.

(Text continues on p. 53)

METAL STAMPING PLANT

EQUIPMENT INVENTORY WORKSHEET # PAGE 1 — # PAGE 1 HARDENING DECISION WORKSHEET

BLDG SIDE BUILDING

AREA

SQUAD MEMBERS [illegible] KAMBUROFF

ITEM NO	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR	E+RR	BLAST	STRUCTURAL	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER MANPOWER	START / COMPLETE	NEW RATING
1	NIAGARA CIRCLE SHEAR	1	H 6' W 2' L 8' DIA	3/8" PLATE CONSTRUCTION BOLTED WITH 3/8" BOLTS (4 EACH)	0	3	2	5	5	2	7		X			TIE TO BOTH CINCINNATI SHEARS (SEE SKETCH)	LENGTHS OF ROD CHANNEL WELDERS FORKLIFT	JOHN + 1	T+2 / T+4	20
2	CINCINNATI SHEAR (SHAPER) 480 V	2	H 5' W 7' L 10' DIA	VERY HEAVY CONSTRUCTION FOUR 3/4" BOLTS TO FLOOR	0	3	2	5	5	2	7		X			TIE TOGETHER AND TO CIRCLE SHEAR (SEE SKETCH)	HAND TOOLS WELDERS BAR AND ROUND STOCK CHANNEL, ETC.	SEE ITEM 5 AND ITEM 7	T+2 / T+10	20
3	WASHER (PRE-PAINTING) FIVE WATER HEATING STATIONS (GAS) MONORAIL CONVEYOR TYPE (CONTINUOUS)	1	H 10' W 10' L 60' DIA	WALLS 1/8" STEEL NOT FASTENED DOWN	0	3	2	5	2	2	7		X			KNOCK DOWN FILL TANKS WITH WATER AND AFFIX TO FLOOR	HAND TOOLS CUTTING TORCHES FORKLIFT	TIM + 2	T+2 / T+10	REPAIRABLE WITH SCRAP AND WELDING 25
4	PAINT SPRAY BOOTH THIN WALL	1	H 8' W 8' L 6' DIA	1/16" WALLS, NOT AFFIXED (OVER)	0	4	4	8	2	2	10		X			KNOCK DOWN	HAND TOOLS CUTTING TORCH	DONE WITH ITEM 3 ABOVE		REPAIRABLE WITH SCRAP AND WELDING 28
5	AIR COMPRESSOR (JOY 10×9) 450 rpm 60 hp	1	H 8' W 6' L 6' DIA	VERTICAL, BOLTED TO HEAVY CONCRETE BASE, 1 FT HIGH WITH 5/8" BOLTS (4)	0	2	2	4	5	2	6			X		TAKE TO SHEARS (SHAPERS) AND TIE (WELD) TO ALL THREE	HAND TOOLS LARGE FORKLIFT ROD AND BAR STOCK	MAINTENANCE FOREMAN + 2	T+2 / T+10	20
6	AIR RECEIVER	1	H 10' W L DIA 3'	3/8" WALLS, 5" INLET NOT FASTENED DOWN	0	3	1	4	0	2	6			X		TAKE TO STORAGE YARD BETWEEN BLDGS, DIG HOLE AND BURY (WITH 1 FT OF COVER). FILL WITH WATER.	HAND TOOLS SMALL FORKLIFT	DONE WITH ITEM 5 ABOVE		34
7	FENDER ROLLER	1	H 3' W 5' L 5' DIA	FOUR 1/2" BOLTS. HEAVY FRAME	0	2	3	5	5	2	7			X		PUT WITH SHAPERS AND AIR COMPRESSOR IN SIDE BLDG EQUIPMENT "STACK"	FORKLIFT HAND TOOLS WELDERS ROD BAR AND CHANNEL STOCK	JOHN + 1	T+4 / T+6	WITH SPECIAL ATTN. 25

DESCRIBE POSSIBLE COLLATERAL DAMAGE
DAMAGE POSSIBLE FROM WOOD AND SHEET METAL WALLS OF BUILDING; HEAVY GAUGE SHEET METAL (STEEL AND ALUMINUM) IN FLATS PILED ON FLOOR (UP TO 8 FT. HIGH) MOSTLY ALONG SOUTH WALL IN NEAT, BUT UNBOUND STACKS (8 PILES OR STACKS); STAMPINGS STACKED UP TO 5 FT. HIGH. WASHER AND DRYER WITH PAINT LINE, THIN-WALLED ASSEMBLY, THREATENS LIGHT EQUIPMENT.

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

← RATING →

PRIORITY = A+B or A+C (lowest sum)

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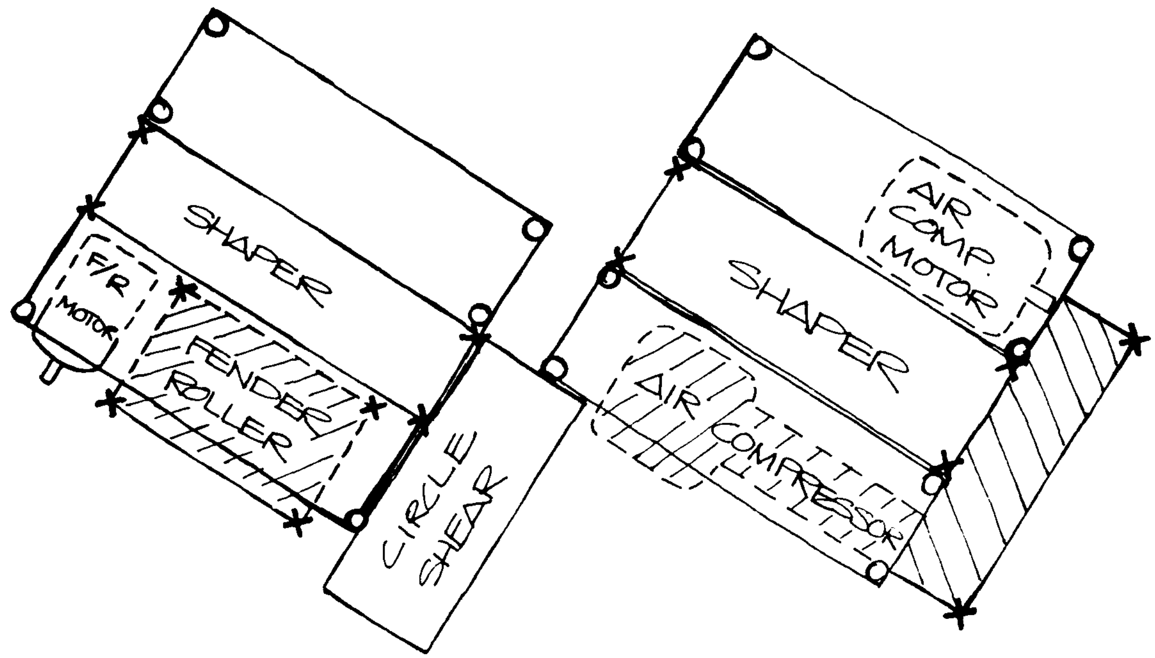
Back of Hardening Decision Worksheet Page 1



X = FASTENING POINTS TO FLOOR

METAL STAMPING PLANT

EQUIPMENT INVENTORY WORKSHEET # PAGE 2 **HARDENING DECISION WORKSHEET** # PAGE 2

BLDG SIDE BUILDING
AREA

SQUAD MEMBERS
J. BOYES
& KAMBUROFF

ITEM NO.	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR	E+RR (A)	BLAST (B)	STRUCTURAL (C)	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER MANPOWER	START/COMPLETE	NEW RATINGS
1	TRIM AND STAMP TABLE WITH DIES AND PNEUMATIC CYLINDER (3 x 10-IN. DIAMETER CYLINDER)	1	H 3' W 4' L 8' DIA	1-IN. THICK TABLE TOP NOT AFFIXED VERY HEAVY	0	4	2	6	6	2	8			X		INVERT PLACE NEXT TO CONCRETE CURB	FORKLIFT HAND TOOLS	JOE C + 2	T+2 / T+3	56
2	WELDING AREA WITH PORTABLE WELDERS (MIG)	3	H 3' W 2' L 5' DIA	SMALL WELDERS AND TABLES	0	2	2	4	4	2	6				X	EVACUATE WELDERS INVERT TABLES DO LAST!	FORKLIFTS TRUCK RAMP	JOE C + OPERATORS (2) ON TRUCK	T+2 / T+5	HOST AREA
3	WATER TEST (DIP) TANK FOR TESTING RADIATORS	1	H 3' W 3' L 8' DIA	NOT AFFIXED	0	2	4	6	2	2	8	X				LEAVE FULL AFFIX TO FLOOR	EQUIPMENT ANCHORS ELECTRIC DRILL HAND TOOLS	N/A	T+3 / T+4	TANK REPAIRABLE WITH SCRAP AND WELDERS 25
4	CONTINUOUS FEED WELDERS ON ARMS BOTTOM PLATE 18" SQUARE	4	H 6' W 4' L 8' DIA	WITH FOUR 1/2-IN. BOLTS	0	4	3	7	3	2	9				X	UNBOLT AND EVACUATE	SMALL FORKLIFT TRUCK HAND TOOLS	JOE C + 2	T+3 / T+5	HOST AREA
5	4,000-lb CAPACITY FORKLIFT	2	H 8' W 4' L 8' DIA	SOLID-TIRED, LPG-POWERED HANDLERS	0	2	3	5	6	2	7				X	PUT ON TRUCK LAST AND EVACUATE WITH PATTERNS AND DIES DO LAST!	RAMP TO TRUCK	OPERATOR JOE C		HOST AREA
6	DIES AND PATTERNS		H W L DIA													PUT ONE IN EACH PRESS AND CLOSE EVACUATE ALL OTHERS				HOST AREA
7	MATERIAL STOCKS		H W L DIA													BAND TOGETHER, LIE FLAT, SOME STACKS PLACED BETWEEN PLATENS OF PRESSES SOME EVACUATED			T+5 / TBD	HOST AREA LEAVE HERE

DESCRIBE POSSIBLE COLLATERAL DAMAGE
STOCKS OF FINISHED RADIATORS, BUMPERS AND FENDERS NEAR MACHINES; SOME IN OPEN, SLATTED CRATES, SOME ON PALLETS

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

← RATING →

PRIORITY = A+B or A+C (lowest sum)

Steel Fabrication Plant

This is a modest plant in the steel fabrication and erection business that employs 25 to 30 people. The hardening assessment conducted at this plant was entirely by SSI personnel (see the following copies of the work-sheets). This planning effort took approximately 32 hours. The lowest Priority before hardening was 6, and the lowest New Rating became 14, for an 8 point, 8 psi, overall improvement in plant vulnerability. The hardening strategy was to move small power and hand tools to host areas and gang anchor and cross brace heavier equipment in stable arrays using steel members and welding equipment on hand. The hardening effort was estimated to be completed by the end of the first day.

(Text continues on p. 63)

STEEL FABRICATION

EQUIPMENT INVENTORY WORKSHEET PAGE # 1 — **HARDENING DECISION WORKSHEET** PAGE # 1

BLDG MAIN BAY

AREA

SQUAD MEMBERS G. KAMBUROFF

ITEM NO.	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR	E+RR (A)	BLAST (B)	STRUCTURAL (C)	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER MANPOWER	START / COMPLETE	NEW RATING
1	ANGLE SHEAR/ STRUCTURAL IRON WORKER	1	H 7' W 2' L 6' DIA	FOUR 1/2-IN. BOLTS TO CONCRETE FLOOR; VERY HEAVY CONSTRUCTION	0	3	2	5	5	2	7	☒				OTHER EQUIPMENT TO BE AFFIXED TO THIS ITEM. MOTOR REMOVED AND AFFIXED UNDERNEATH BETWEEN SUPPORTS.	BRIDGE CRANE; HAND TOOLS; WELDER	SEE SCHEDULE	T+3 / T+7	≈15
2	CINCINNATI/ CENTURY SHEAR	1	H 7' W 12' L 4' DIA	1/2-IN. BOLTS TO CONCRETE (MORE THAN 10)	0	2	2	4	5	2	6	☒				OTHER EQUIPMENT TO BE AFFIXED TO SHEAR. CONTROLS REMOVED AND EVACUATED	BRIDGE CRANE; HAND TOOLS; WELDER		T+3 / T+7	≈14
3	CUTTING TABLE– 1/2" x 4' ON EDGE	1	H 3' W 6' L 30' DIA	NOT AFFIXED	0	4	4	8	6	2	10			☒		INVERT AND AFFIX TO REAR OF SHEAR UNDER WORK TABLE	HOIST; CRANE		T+3 / T+7	≈10
4	VERTICAL BORING MACHINE	1	H 8' W 3' L 7' DIA	NOT AFFIXED; HEAVY BASE	0	3	2	5	5	2	7			☒		LOWER CENTER OF GRAVITY AND WELD OR TIE TO CINCINNATI SHEAR; BOLT DOWN	WELDER; BAR STOCK; "RED HEADS" (ANCHORS); 1/2-IN. BOLTS		T+3 / T+7	≈15
5	SMALL SAND BLASTER (SAND TANK)	1	H 4' W L DIA 2'	PORTABLE; ON 18-IN. WHEELS	0	3	3	6	5	2	8				☒	EVACUATE WITH COMPANY TRUCK	NONE		T+1 / T+3	HOST AREA
6	THREADING MACHINE 3 hp	1	H 5' W 2' L 5' DIA	FOUR 1/2-IN. BOLTS; TOP HEAVY; NOT AFFIXED	0	3	2	5	5	2	7				☒	EVACUATE WITH COMPANY TRUCK	BRIDGE CRANE; CHAIN		T+1 / T+3	HOST AREA
7	SMALL CUTOFF SAW	1	H 4' W 2' L 3' DIA	LIGHT; NOT AFFIXED	0	3	3	6	6	2	8				☒	EVACUATE WITH COMPANY TRUCK	BRIDGE CRANE; CHAIN			HOST AREA

DESCRIBE POSSIBLE COLLATERAL DAMAGE

COLLATERAL DAMAGE POSSIBLE FROM STOCKED SUPPLIES INCLUDING I BEAMS, PLATE, ROUNDS, etc.
BRICK BUILDING ACROSS STREET (TO THE WEST)

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

← RATING →

PRIORITY = A+B or A+C (lowest sum)

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STEEL FABRICATION

EQUIPMENT INVENTORY WORKSHEET PAGE # 2 — PAGE # 2 **HARDENING DECISION WORKSHEET**

BLDG. MAIN BAY — SQUAD MEMBERS

AREA

ITEM NO	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR	E+RR (A)	BLAST (B)	STRUCTURAL (C)	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER/MANPOWER	START/COMPLETE	NEW RATING
1	DOUBLE ENDED PUNCH	1	H 8'; W 4'; L 10'; DIA	VERY HEAVY CASTINGS; WITH EIGHT 1/2-IN. BOLTS	0	3	3	6	5	2	8	X				TO HAVE OTHER ITEMS ATTACHED AND AFFIXED TO COLUMN FOOTINGS	BRIDGE CRANE; WELDERS; HAND TOOLS	SEE SCHEDULE	T+3 / T+7	≈10
2	PUNCH PRESS	1	H 6'; W 3'; L 3'; DIA	VERY TOPHEAVY; NOT AFFIXED	0	3	3	6	5	2	8		X			CHANGE CENTER OF GRAVITY, ATTACH AND SECURE TO PUNCH	BRIDGE CRANE; WELDERS; HAND TOOLS		T+3 / T+7	≥10
3	CUTOFF SAW ≃ 21 IN. BLADE	1	H 5'; W 4'; L 6'; DIA	TOPHEAVY; NOT AFFIXED	0	3	3	6	5	2	8				X	EVACUATE	BRIDGE CRANE; TRUCK		T+6 / T+10:30	HOST AREA
4	BENDING TABLE	1	H 4'; W 2'; L 3'; DIA	TOPHEAVY; NOT AFFIXED	0	3	3	6	5	2	8				X	EVACUATE	BRIDGE CRANE; TRUCK		T+1 / T+3	HOST AREA
5	IDEALARC TM 500 WELDERS	4	H 3'; W 2'; L 3'; DIA	NOT AFFIXED	0	2	2	4	2	2	6				X	EVACUATE	BRIDGE CRANE; TRUCK		T+9 / T+10	HOST AREA
6	M-G SETS (WELDERS, D.C.)	3	H 3'; W; L; DIA 18"	NOT AFFIXED	0	3	2	5	3	2	7				X	EVACUATE IF ROOM ON TRUCK AND IF TIME PERMITS OTHERWISE, PLACE ON FLOOR AND TIE TOGETHER	USE THESE TO WELD FRAME AROUND; MAKE STEEL BOX TIE DOWN		T+7 / T+8	≥20
7	I/R AIR COMPRESSOR – HORIZONTAL	1	H 4'; W 4'; L 16-18'; DIA	SIX OR EIGHT 1/2" BOLTS	0	2	2	4	5	2	6	X				REMOVE MOTOR AND FLYWHEEL, BELTS & GUARDS; FASTEN TO FLOOR WITH ADDITIONAL ANCHORS SAND BAG	HAND TOOLS; EQUIPMENT ANCHORS; SANDBAGS		T+7 / T+8	≥14

DESCRIBE POSSIBLE COLLATERAL DAMAGE

COLLATERAL DAMAGE LIKELY FROM RACKS AND PILES OF STEEL SUPPLIES (ANGLES, BARS, ROUNDS, PLATE, FLAT STOCK, etc.)

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

RATING (columns A, B, C)

PRIORITY = A+B or A+C (lowest sum)

STEEL FABRICATION

EQUIPMENT INVENTORY WORKSHEET PAGE # 3 — **HARDENING DECISION WORKSHEET** PAGE # 3

BLDG. SIDE BAY
AREA

SQUAD MEMBERS
G KANBUROFF

ITEM NO.	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR	E+RR	BLAST	STRUCTURAL	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER/MANPOWER	START/COMPLETION	NEW RATING
1	BRIDGE CRANE. ELECTRIC 5-TON; 40-FT. SPAN	1	H W L DIA	ON STEEL BEAMS DOWN CENTER OF BAY WIDE-FLANGED BEAMS ON WOODEN POSTS	0	3	2	5	6	2	7			X		DROP TO GROUND WELD BRIDGE ACROSS STRUCTURAL COLUMNS AT GROUND LEVEL. EVACUATE HOIST	SAVE UNTIL LAST	SEE SCHEDULE	T+9 / T+10	HOST AREA
2	ONE-TON HOIST ON MONORAIL	3	H 1' W 2' L 1' DIA	HELD WITH ONE 3/4-IN BOLT TO TROLLEY	0	3	2	5	6	2	7				X	EVACUATE WITH COMPANY TRUCK	HAND TOOLS HAND TRUCK/CART		T+8 / T 4030	HOST AREA
3	HYDRAULIC POWER KIT FOR TOOLS AND ATTACHMENTS	1	H 2' W 3' L 2' DIA	HEAVY DUTY PUMPS. FRAME AND OIL STORAGE TANK SKID-MOUNTED/PORTABLE	0	3	2	5	6	2	7				X	EVACUATE WITH COMPANY TRUCK	HAND TRUCK/CART		T+1 / T+3	HOST AREA
4	WEB PUNCH (HYDRAULIC) FOR USE WITH ABOVE	1	H 10" W 12" L 12" DIA	VERY HEAVY FRAME PORTABLE	0	3	2	5	6	2	7				X	EVACUATE WITH COMPANY TRUCK	HAND TRUCK/CART		T+1 / T+3	HOST AREA
5	SMALL DRILL PRESS		H 5' W 2' L 2' DIA	MOVABLE, NOT AFFIXED	0	3	2	5	4	2	7				X	EVACUATE WITH COMPANY TRUCK	HAND TRUCK/CART		T+1 / T+3	HOST AREA
6	WEB PUNCH (LARGE)		H 5' W 2' L 3' DIA	MOVABLE, NOT AFFIXED	0	3	2	5	6	2	7				X	EVACUATE WITH COMPANY TRUCK	HAND TRUCK/CART		T+1 / T+3	HOST AREA
7	RACKS FULL OF STEEL STOCK WIDE FLANGES, ANGLES FLATS, ROUNDS, CHANNELS, PLATES		H W L 20'-30' DIA	SOME BANDED TOGETHER; OTHERS LOOSE IN RACKS	PROTECTIVE HOUSEKEEPING			PROTECTIVE HOUSEKEEPING								MOST TO BE TIED TOGETHER AND PUT ON FLOOR. SOME TO BE EVACUATED FOR USE IN SHELTER CONSTRUCTION (HOST AREA)	BRIDGE CRANE. HOISTS. WELDER BANDING TOOLS		T+1 / T+10	

DESCRIBE POSSIBLE COLLATERAL DAMAGE

SITUATED IN OPEN-ENDED, STEEL-FRAMED STRUCTURE WITH ONE OPEN SIDE (OTHER SIDE AGAINST WOODEN WALL OF MAIN BAY).

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

← RATING →

PRIORITY = A+B or A+C (lowest sum)

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STEEL FABRICATION

RESOURCE INVENTORY FORM

TYPE Steel TEAM # 1 SHEET # 1 AREA plant

TIME: START 2:30 FINISH 2:45 CHECKED

NUMBER	DESCRIPTION OF ITEM	Location	QUANTITY	PRE	POST
1	Welders	various	8	✓	
2	Torches	various	4	✓	
3	Use steel members to build frames around machines to protect from building collapse.				
4					
5					
6					
7					
8					
9					
10					

Food Processor

Two food processing plants provided pertinent information on industrial preparedness, though not of the sort expected. One plant was a packager and exporter of dried fruits, the other was a large canner of tomato products, and each had several hundred employees. Figures 10 and 11 show pictures taken at the canning plant. No data sheets were completed for reasons that will become apparent.

At all plants, eventually, there arises the question what equipment the plant could do without in a serious emergency. The initial answer is generally about the same,"Nothing can be done without" - - - "We need all of it, that's why we have it."

To cut through this inertia takes about a half hour of serious discussion to set the scene regarding what conditions might be like after a nuclear attack. For the few who rebel at this thought altogether, discussion remains fixed on natural disasters such as earthquakes, hurricanes, tornadoes, and the great similarities in damage (just not quite so widespread). Most begin to get the circumstances pictured well enough eventually to see alternatives. At both food processing plants the answer changed to "We don't need any of it [the plant and the equipment]." In one case this was because all the important processing [fruit drying] takes place near where it is grown, and the fruit is shipped to the plant for packaging only. At the second plant (see Appendix A for the detailed exchange) a similar type of response was made — but in this case there was an immediate realization that equipment could be converted to pasteurize milk or to process meat. This would require saving only a steam source, the cooker, and the canner, which would not take a great deal of manpower or time.

(Text continues on p. 67)

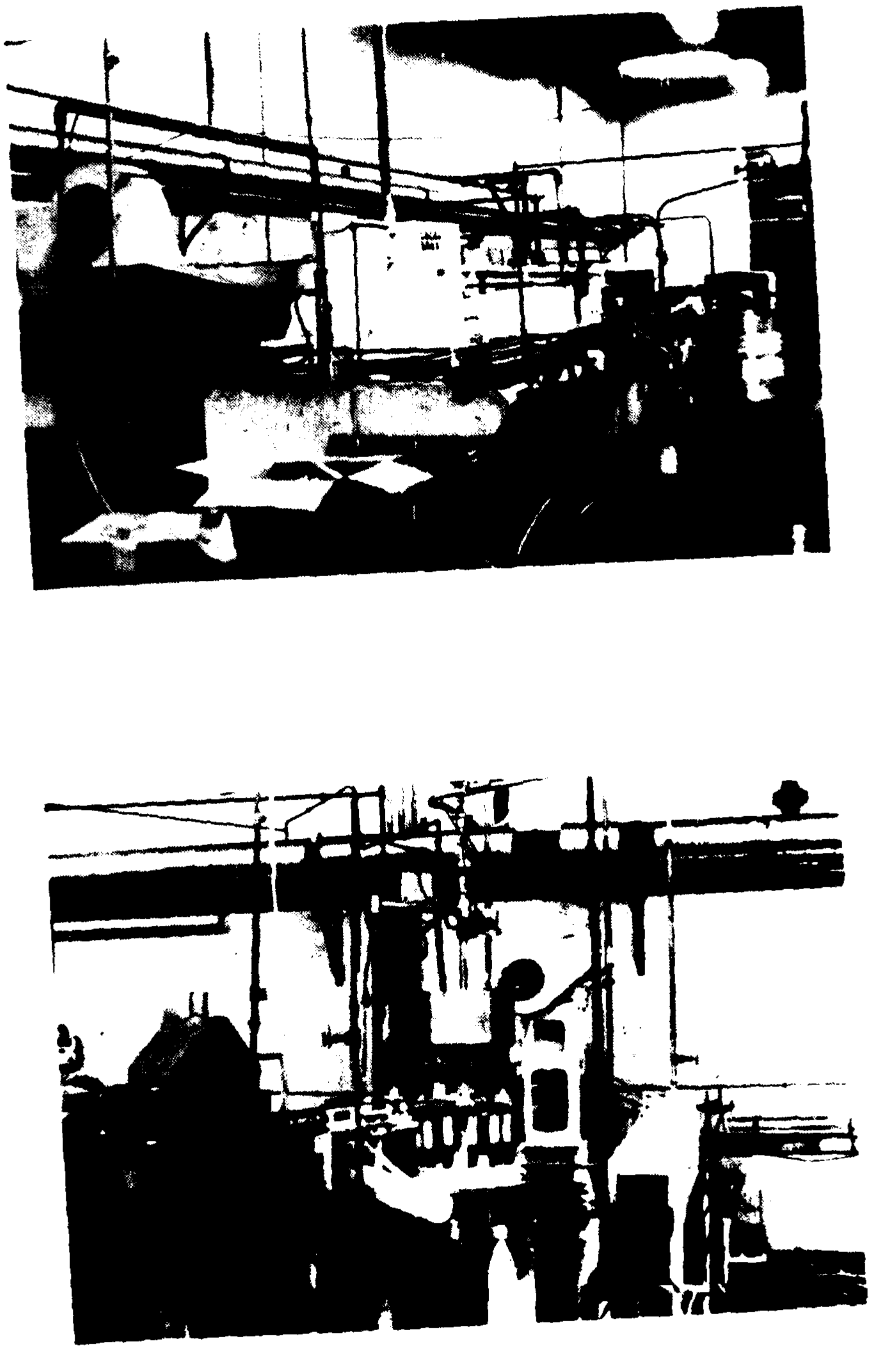
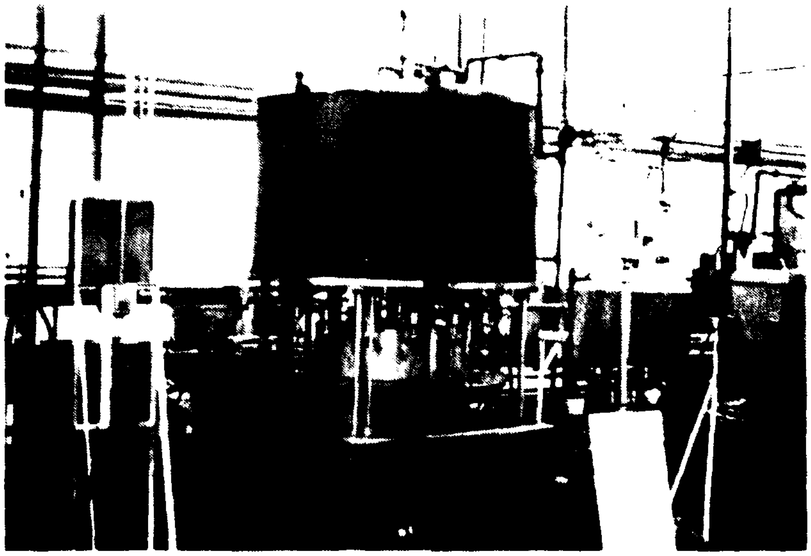


Fig. 10. Food Canning Plant.



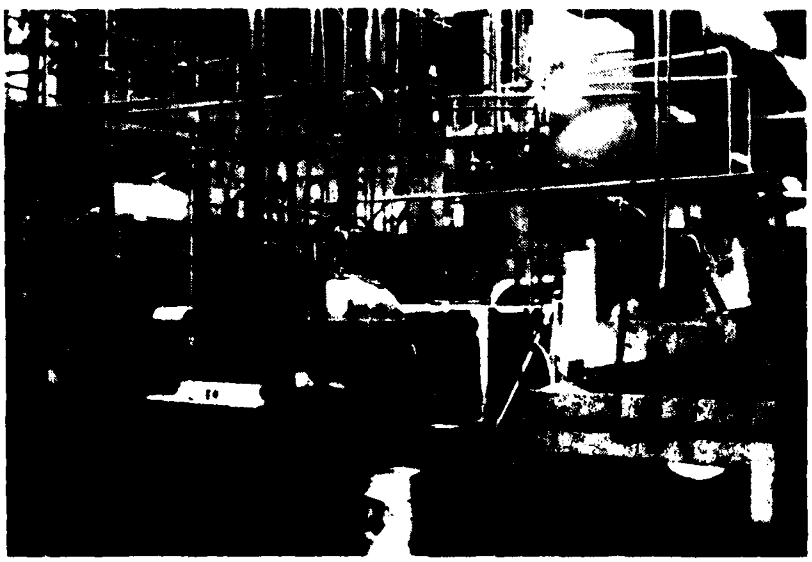


Fig. 11. Food Canning Plant.

Utility

This was a large water utility serving several million people. Though no data sheets were completed by either SSI or plant personnel, two utility representatives read most of the booklets and met with SSI personnel to discuss the manual. By its nature, this particular utility is already well dispersed. In many locations in the region it serves, the water supply is from underground wells that are tapped by local pumps, electrically powered. For emergency situations, when power is unavailable, a number of gasoline-powered mobile units with diesel-powered pumps are maintained, which could be dispatched to critical areas, post-attack.

The utility's reviewers did not believe a self-help plan for hardening applicable in their case, though they concurred that early planning and last minute action were most probable modes of response. The hardening and relocation aspects did not seem practical in view of the fact that the company is already largely decentralized with a significant portion of the water supply coming from widely dispersed wells. Moreover, they didn't believe more than one or two individuals capable of effective response would report when it was finally and obviously time for last minute action.

The reviewers provided two recommendations, based on their particular situation. Some means for an effective public communication system to locate their competent, experienced personnel, post-attack, for recovery operations, would be the most valuable part of any company plan. And, assurance of a long-term fuel supply to operate the emergency units would be required because their disaster scenarios are based on short-term emergencies.

PHASE II — HARDENING EXERCISES

For this program element, four hardening exercises were conducted on-site, and empirical data on time, manpower, materials, and techniques applied were obtained for comparison with analytical data. Slides and movies were made for presentations. These onsite demonstration exercises covered the three major types of preparedness protection — harden-in-place, evacuate, and relocate nearby and harden. The first type of hardening exercise was conducted at one plant by SSI personnel, and the other two types were conducted entirely by industry personnel at the plants involved.

Harden-In-Place Demonstration

As noted in the Phase I section of this report, there are a number of activities associated with the harden-in-place alternative. For example, these include: the management decision to use such factors as size and vulnerability of equipment, type of structure in which equipment is located, whether the industry is essential and must be kept operating as long as possible, etc.; a screening process to determine which equipment and processes are essential and must be protected; a resource inventory to determine the types of hardening alternatives that can be used; and the protective housekeeping phase of industrial protection. Under protective housekeeping a number of activities are performed, such as: protection of vital records; removal of flammable materials; unhooking power and fuel lines; removing or covering vulnerable gauges, controls, handles, etc.; and many other simple activities that greatly reduce the vulnerability of equipment and structures to blast, fire, and EMP.

The particular plant available for the harden-in-place exercise was a wood products plant located in Cloverdale, California. This plant is several acres in extent with well over an acre of buildings. The project

team was permitted relatively unlimited access to the facility during a month-long shutdown period. The machines located in the plant were, of course, associated with various woodcutting and shaping activities, but were also of a size and weight typical of a wide variety of machine tools used for other manufacturing processes. Overall views of the facility and some of the typical equipment are shown in Figures 12 through 17.

As in the Phase I analyses, the hardening procedures conducted have included an essential-equipment selection process, determination of the protective housekeeping measures applicable to the plant and to each piece of equipment, and estimates of time in man-hours to complete each task. These are summarized in the attached data sheets completed by SSI personnel. The assessment took only a few hours, and the expected improvement in vulnerability rating was 18 points, corresponding to a jump from 2 psi to 20 psi.

Since the primary damage parameter for most of the essential equipment would be collapse of the relatively weak, but also relatively light, wooden structures, the primary hardening measure used was to cover the machines with sandbags, as shown in Figures 18 through 25. Figures 18 through 21 show the sandbagging sequence for a planer and Figures 22 through 25, a similar sequence for a joiner. With regard to the planer it will be noted that a number of sheet metal pipes, which are used for dust collectors, remain in view. These, of course, would be removed during the actual hardening process, but to avoid damage to the equipment they were not removed for this demonstration. It was also determined that this relatively light sandbag covering would protect the equipment from building collapse and, if necessary, fire. To protect the machines, individually, would require 25,000 sandbags — or heavy plastic sheet, an end-loader, and several hundred yards of sand or dirt.

It was interesting to note in this plant that almost all the heavy equipment was skid-mounted and not affixed securely to the floor (see, for example, Figures 14 and 22). This has been noted in many plants where

equipment is either lightly fastened to the floor or not fastened at all. This points up the fact that in-place hardening will in many cases require the more secure fastening of equipment to the floor (probably during the protective housekeeping operation). However, it also facilitates an effective alternative. Where equipment is not bolted down, and particularly where it is skid-mounted, rapid movement of many items of equipment out of the structure is possible. To demonstrate this, the joiner used in the previous demonstration was moved into an open area near the plant and hardened using stacks of lumber (readily available), sandbags, and cable tiedowns. This procedure is shown in Figures 26 through 28.

If all the important equipment were skidded out of the plant structure, gathered in a clump, and sandbagged, the number of sandbags required would be reduced by half or more, and so would the time required for hardening. Moreover, bolting might prove totally unnecessary in this case. For example, Figures 29 through 32, compared with Figures 33 through 36, provide a simple graphic summary of the change in stability and in quantities of sandbags required when the horizontal dimension of the array is made large relative to the vertical dimension. The more stable configuration is also considerably easier to stack sandbags around.

(Text continues on p. 87)

Fig. 12. View Outside One End of the Wood Products Plant.

Fig. 13. View Inside the End Building Visible in Figure 12.

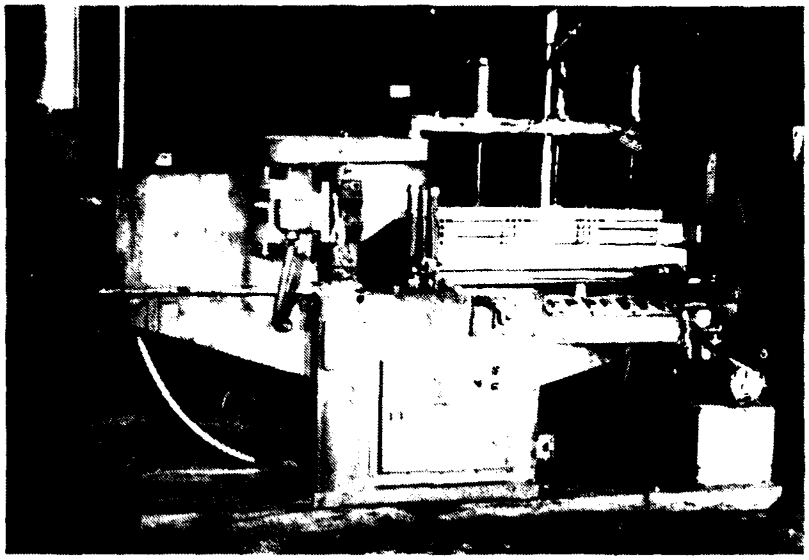


Fig. 14. Skid-Mounted 48-inch Twin Spindle Profile Shaper.

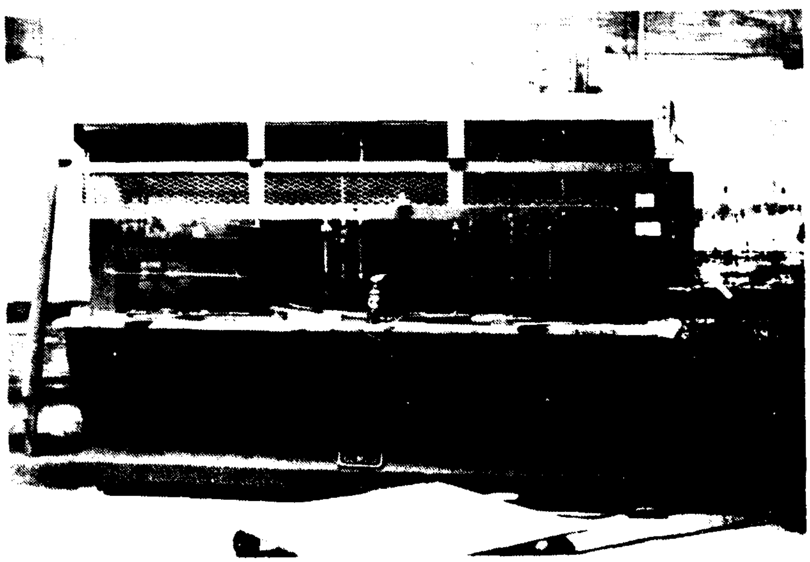


Fig. 15. CEMCO Multiple Drill.

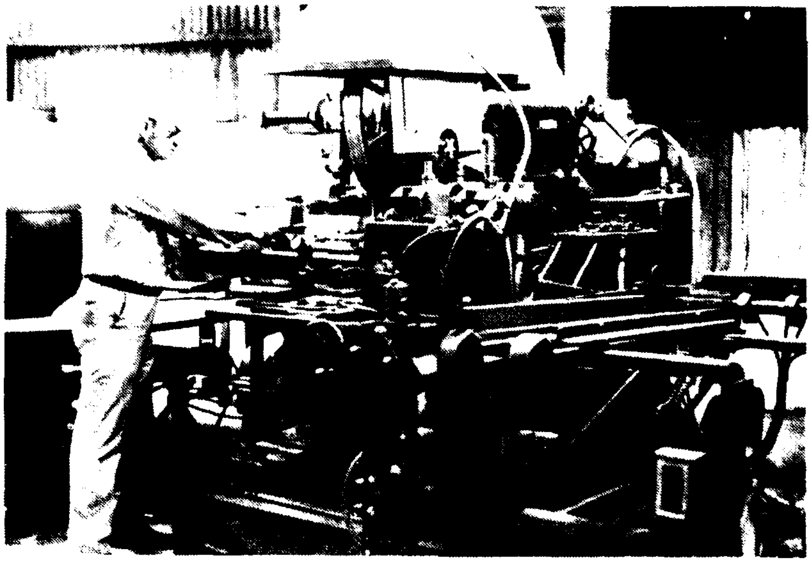


Fig. 16. Twin Band Mershon Resaw.

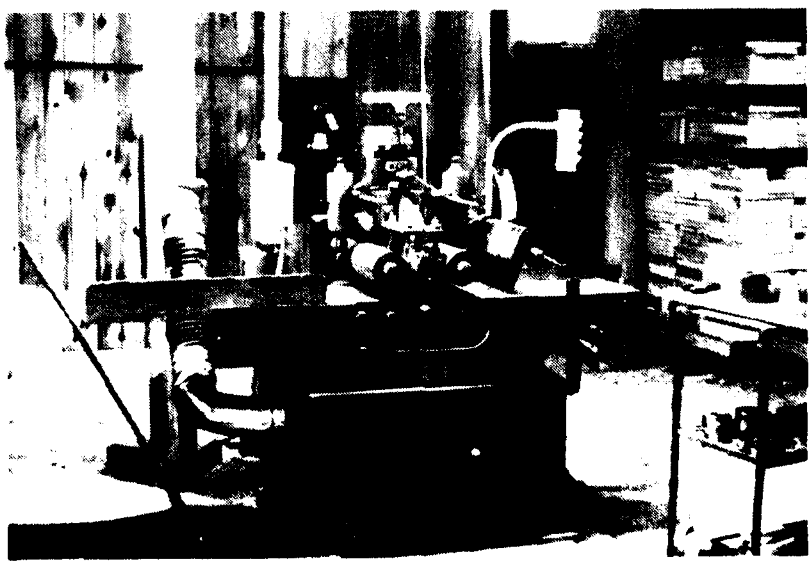


Fig. 17. Moulder.

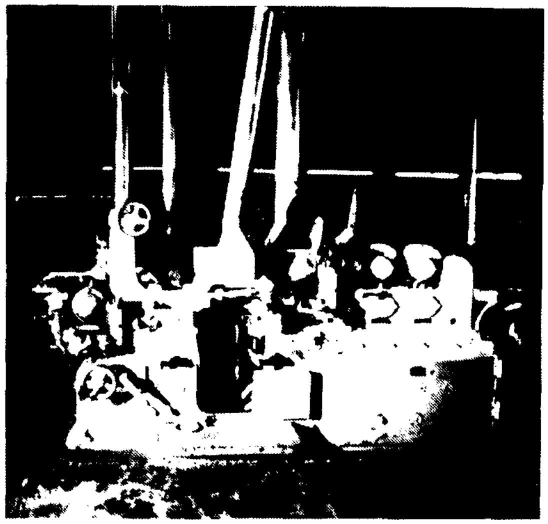


Fig. 18. Yates Moulder.

Fig. 19. Yates Moulder at First Stage of Hardening.

Fig. 20. Moulder at Two-Thirds Stage of Hardening.

Fig. 21. Moulder Completely Hardened.

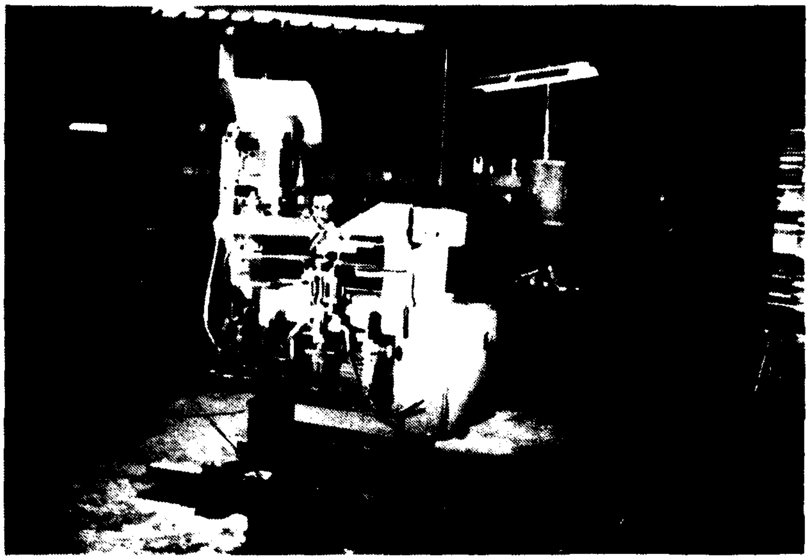


Fig. 22. Joiner Before Hardening.

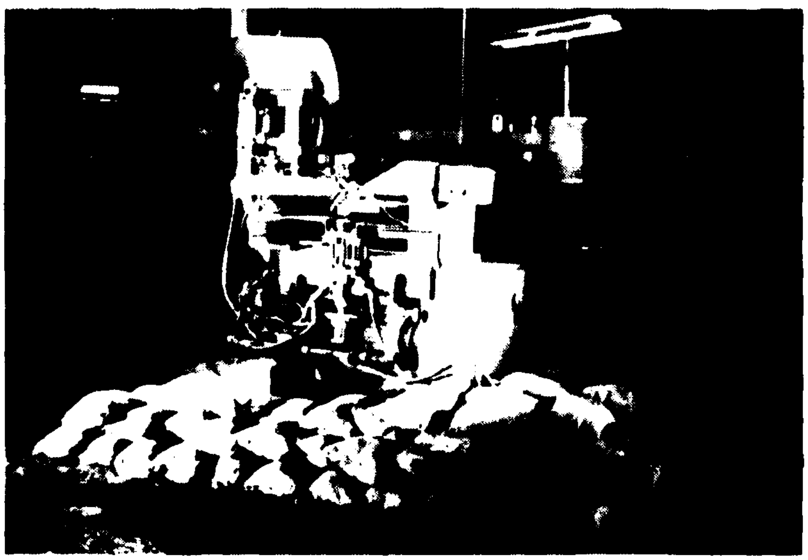


Fig. 23. Joiner With Beginning Layer of Sandbags.

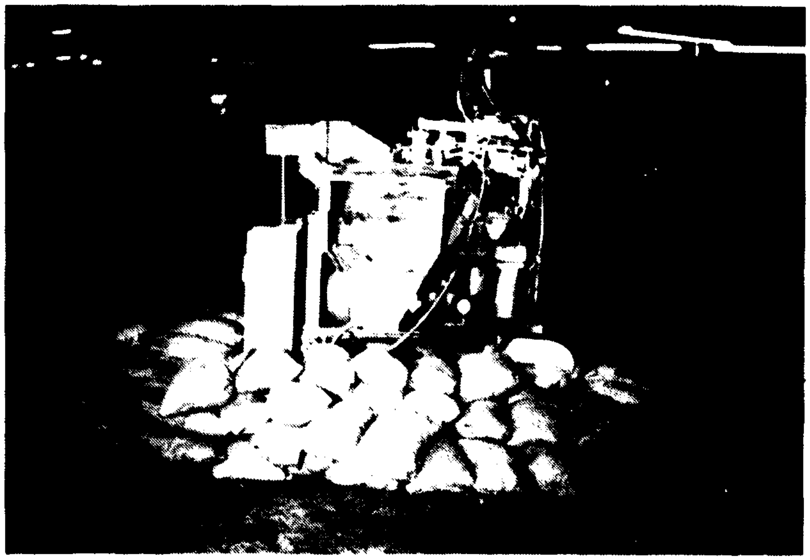


Fig. 24. Joiner, View from Opposite Side.

Fig. 25. Joiner Completely Covered.

Fig. 26. Joiner Moved Outside With Stacks of Wood Placed On Either Side.

Fig. 27. Joiner Partially Covered With Sandbags.

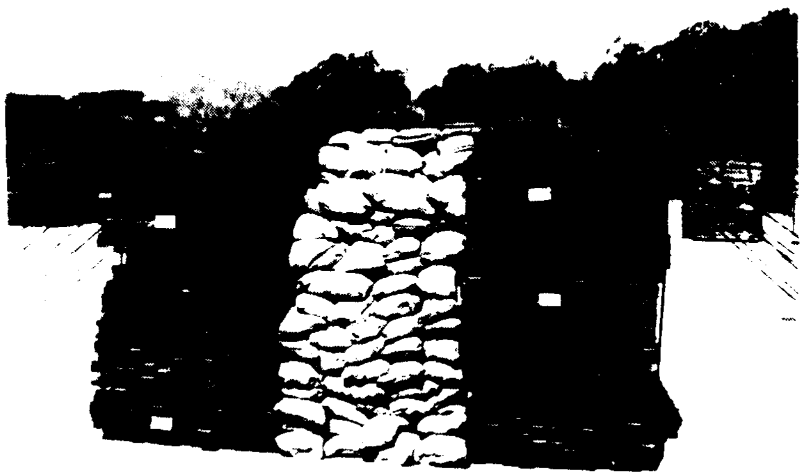


Fig. 28. Joiner Hardening Completed.

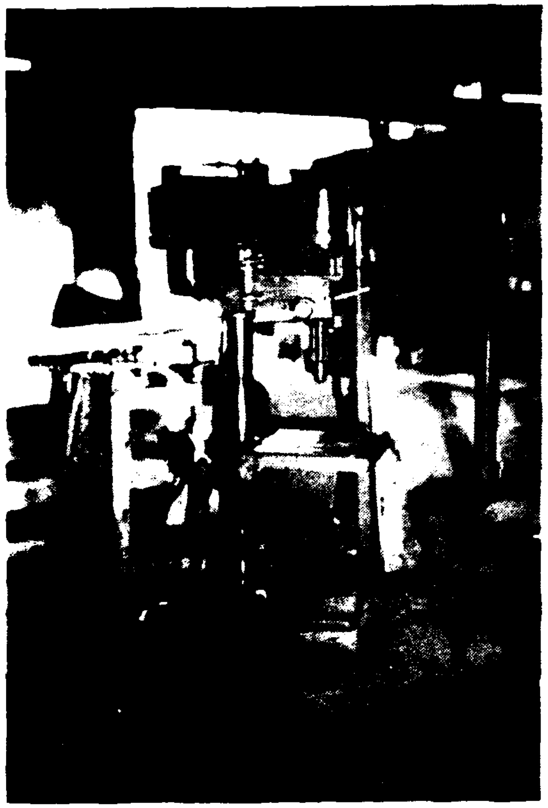


Fig. 29. Fixed Drill Press — Operating Position

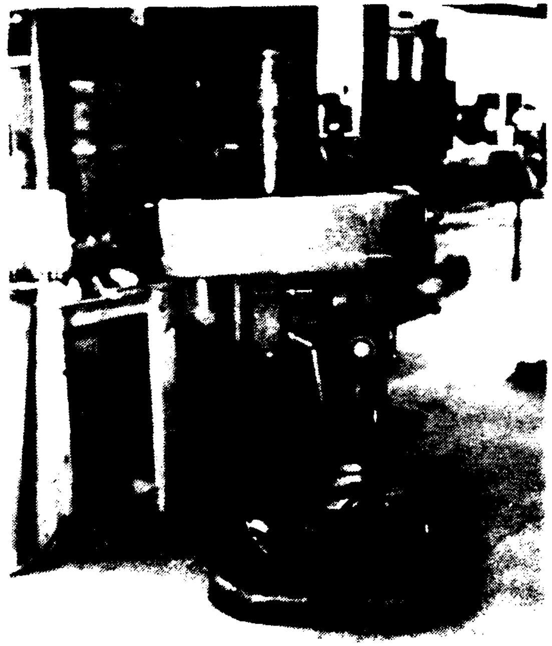


Fig. 30. Fixed Drill Press — Center of Gravity Minimized.

Fig. 31. Fixed Drill Press — First Stage of Hardening.

Fig. 32. Fixed Drill Press — Hardened.

Fig. 33. Free Drill Press — Center of Gravity Optimized.

Fig. 34. Free Drill Press — First Stage of Hardening.

Fig. 35. Free Drill Press — Second Stage of Hardening.

Fig. 36. Free Drill Press — Hardened.

EQUIPMENT INVENTORY WORKSHEET # 1

BLDG. EAST
AREA MAIN

SQUAD MEMBERS JOHN

\# 1 HARDENING DECISION WORKSHEET

No.	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR	E+RR	BLAST	STRUCTURAL	PRIORITY	FORGET IT / HARDEN IN PLACE / MOVE AND HARDEN / EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER MANPOWER	START / COMPLETE	NEW RATING
1	RESAW	2		ON SKIDS	0			2	3	2	4	X	BOLT TO FLOOR SANDBAG	CONCRETE DRILL ANCHORS SANDBAGS	- 24 MEN	TH T+9	23
2	MULTIPLE DRILL	1		LOOSELY TIED WITH SMALL BOLTS	0			2	2	2	4	X	BOLT TO FLOOR SANDBAG	CONCRETE DRILL ANCHORS SANDBAGS	12 MEN	T+9 T+17	22
3	TENONER	4		ON SKIDS	0			2	3	2	4	X	BOLT TO FLOOR SANDBAG	CONCRETE DRILL ANCHORS SANDBAGS	24 MEN	T+9 T+29	23
4	MOULDER	2		BOLTED, SMALL	0			2	3	2	4	X	BOLT TO FLOOR SANDBAG	CONCRETE DRILL ANCHORS SANDBAGS	24 MEN	T+29 T+37	23
5	RIPSAW	1		BOLTED, SMALL	0			2	2	2	4	X	BOLT TO FLOOR SANDBAG	CONCRETE DRILL ANCHORS SANDBAGS	12 MEN	T+37 T+45	22
6																	
7																	

SIZE column sub-rows: H, W, L, SA.

RATING (E+RR, BLAST, STRUCTURAL, PRIORITY)

DESCRIBE POSSIBLE COLLATERAL DAMAGE

WOOD STRUCTURE COLLAPSE AT [illegible] PSI

STACKS OF LUMBER IN YARD AT [illegible]5 PSI

,000 MANHOURS INDIVIDUALLY 2 DAYS WITH 3 SHIFTS

500 MANHOURS CLOSE PACKED 1 DAY WITH 3 SHIFTS.

USE BACK OF THIS WORKSHEET FOR SKETCH SHOWING EQUIPMENT LOCATION, IF DESIRED

Relocation Demonstration #1

The small job shop that participated in this demonstration is representative not only of its type, but also of a small maintenance shop that might be part of a moderate sized manufacturing company. It is a one-man operation specializing in one-of-a-kind parts and minor electrical testing.

Total evacuation of the shop was determined to be the most efficient hardening technique for two principal reasons. First, being a small job shop accustomed to purchasing materials as needed, there were few materials available for in-place hardening. Second, the shop owned a light truck, which appeared capable of carrying a major portion, if not all, of the shop equipment.

The evacuation was carried out by two sons of the shop owner, under the owner's supervision. Shop equipment included several still cameras, and a movie camera with which the owner recorded his sons in action. The shop owner felt that the evacuation could be carried out either by two inexperienced people under supervision (as here), or by two people alone, provided that at least one had experience in efficient and safe loading of trucks.

The heavy shop equipment was loaded on the truck first. The equipment was moved with a hand-pushed forklift, a handtruck, and pipe rollers. The truck had a lift gate, which was used along with the forklift, to raise the equipment into the truck bed. After the heavy equipment was loaded, the storage cabinets were emptied of the fragile electronic equipment and loaded flat on the truck bed. The electronic equipment was then replaced in the cabinets to protect it during transport. Once the delicate equipment had been taken care of, remaining small handtools and other small non-fragile equipment were loaded into open 55-gallon barrels and the

barrels stacked on top of the cabinets. A small milling machine was also placed on top of the cabinets.

After loading, the shop equipment was secured with tarps and rope in a manner the shop owner felt would be sufficient for traveling several hundred miles without loss or damage. The entire loading procedure was accomplished in $5\frac{1}{2}$ hours by two persons. If necessary, the forklift used for loading could have been replaced with a chain hoist and an A frame, but additional time would have been required.

Both SSI and the shop owner performed hardening analyses, using the manual prior to actual performance of the evacuation. The shop owner, in the course of the evacuation exercise, found that his estimate, and the estimate made by SSI personnel, of the amount of equipment that could be loaded on the truck fell significantly short of the actuality. In addition to the items listed on the equipment inventory sheets (see data sheets following this discussion), a mill, an acetylene torch (oxygen and acetylene bottles), a grinder, disc and belt sander, miscellaneous supplies, supply cabinets with nuts and bolts, and a 15-amp, 220-volt single phase gasoline-powered electrical generator were loaded on the truck.

Survival of a number of these small job shops could make an invaluable contribution in a post-disaster environment. The shop in this study, given fuel to run its generator, could start, almost immediately, to manufacture replacement parts for damaged equipment. Presuming that the shop owner was able to move his truck to an unimpacted area, he need merely unload his equipment into some shelter, obtain working stock and gasoline, and begin operation.

(Text continues on p. 97)

SMALL JOB SHOP

EQUIPMENT INVENTORY WORKSHEET PAGE #: 1

BLDG. ______
AREA ______

SQUAD MEMBERS ______

ITEM NO	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR
1	BAND SAW	1	H 4' W 4' L 3' WA	FREESTANDING	0		
2	DRILL PRESS	1	H 0' W 3' L 3 WA	FREESTANDING	0		
3	BENCH LATHE	1	H 2' W 5' L 2' WA	FREESTANDING	0		
4	WELDER	1	H 2½' W 1½' L 1½' WA	FREESTANDING	0		
5	PORTABLE COMPRESSOR	1	H 2' W 3½' L 1½' WA	FREESTANDING	0		
6	STAKE TRUCK	1	H W L WA		0		
7	PIPE DIES AND WRENCHES	SET	H W L WA		0		

DESCRIBE POSSIBLE COLLATERAL DAMAGE

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION IF DESIRED

PAGE #: 1 HARDENING DECISION WORKSHEET

A E+RR	B BLAST	C STRUCTURAL	PRIORITY	PROTECT IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER MANPOWER	START / COMPLETE	NEW RATING
							X	LOAD ON STAKE TRUCK AND EVACUATE	HAND TRUCK	2 MEN ½ hrs	T+1 / T+1½	
							X	LOAD ON STAKE TRUCK AND EVACUATE	HAND TRUCK	2 MEN ½ hrs	T+1½ / T+2	
							X	LOAD ON STAKE TRUCK AND EVACUATE	HAND TRUCK	2 MEN ½ hrs	T+2 / T+2½	
							X	LOAD ON STAKE TRUCK AND EVACUATE	HAND TRUCK	2 MEN ½ hrs	T+2½ / T+3	
							X	LOAD ON STAKE TRUCK AND EVACUATE	HAND TRUCK	2 MEN ¼ hrs	T+3 / T+3¼	
							X	LOAD AND EVACUATE	GASOLINE	2 MEN 1 hrs	T+5 / T+6	
							X	LOAD ON STAKE TRUCK AND EVACUATE	HAND TRUCK	2 MEN ¼ hrs	T+3¼ / T+3½	

← RATING →

PRIORITY = A+B or A+C (lowest sum)

SMALL JOB SHOP

EQUIPMENT INVENTORY WORKSHEET # PAGE 2

BLDG ____

AREA ____

SQUAD MEMBERS ____

ITEM Nº	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR
1	HAND TOOLS IN BOX	SET	H 1' W 2' L 1' DIA		0		
2	RECORDER. 24-CHANNEL	2	H 2½' W 1½' L 1½' DIA	FREESTANDING	0		
3	PHOTOGRAPHIC EQUIPMENT	SET	H 1½' W 2' L 1½' DIA	FREESTANDING	0		
4	CABINETS OF MISCELLANEOUS ELECTRONIC TEST EQUIPMENT	3	H 6' W 5' L 1½' DIA	FREESTANDING	0		
5			H W L DIA				
6			H W L DIA				
7			H W L DIA				

DESCRIBE POSSIBLE COLLATERAL DAMAGE

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION IF DESIRED

_2_ PAGE HARDENING DECISION WORKSHEET

ITEM Nº	E+RR	BLAST	STRUCTURAL	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER MANPOWER	START / COMPLETE	NEW RATING
1								X	LOAD ON STAKE TRUCK AND EVACUATE	HAND TRUCK	2 MEN ¼ hrs	T+3½ / T+3¾	
2								X	LOAD ON STAKE TRUCK AND EVACUATE	HAND TRUCK	2 MEN ¼ hrs	T+3¾ / T+4	
3								X	LOAD ON STAKE TRUCK AND EVACUATE	HAND TRUCK	2 MEN ½ hrs	T+4 / T+4½	
4								X	LOAD ON STAKE TRUCK AND EVACUATE	HAND TRUCK	2 MEN ½ hrs	T+4½ / T+5	
5													
6													
7													

← RATING →

PRIORITY = A+B or A+C (lowest sum)

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SMALL JOB SHOP

EQUIPMENT INVENTORY WORKSHEET
PAGE # 1

BLDG. ______
AREA ______

SQUAD MEMBERS ______

ITEM NO.	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR
1	BAND SAW	1	H 4' W 4' L 3' DIA	FREESTANDING	0	3	3
2	DRILL PRESS	1	H 6' W 3' L 3' DIA	FREESTANDING	0	2	3
3	BENCH LATHE	1	H 2' W 5' L 2' DIA	FREESTANDING	0	3	2
4	WELDER	1	H 2½' W 1½' L 1½' DIA	FREESTANDING	0	2	2
5	PORTABLE COMPRESSOR	1	H 2' W 3½' L 1½' DIA	FREESTANDING	0	3	3
6	STAKE TRUCK	1	H W L DIA		0	2	2
7	PIPE DIES AND WRENCHES	SET	H W L DIA		0	3	2

DESCRIBE POSSIBLE COLLATERAL DAMAGE

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED.

HARDENING DECISION WORKSHEET
PAGE # 1

E+RR A	BLAST B	STRUCTURAL C	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER MANPOWER	START COMPLETE	NEW RATING
							X	LOAD ON STAKE TRUCK AND EVACUATE	TRUCK	2 MEN 5 hrs		
							X	LOAD ON STAKE TRUCK AND EVACUATE	TRUCK	2 MEN 5 hrs		
							X	LOAD ON STAKE TRUCK AND EVACUATE	TRUCK	2 MEN 5 hrs		
							X	LOAD ON STAKE TRUCK AND EVACUATE	TRUCK	2 MEN 5 hrs		
							X	LOAD ON STAKE TRUCK AND EVACUATE	TRUCK	2 MEN 5 hrs		
							X	LOAD AND EVACUATE	GASOLINE	2 MEN 5 hrs		
							X	LOAD ON STAKE TRUCK AND EVACUATE	TRUCK	2 MEN 5 hrs		

← RATING →

PRIORITY = A+B or A+C (lowest sum)

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SMALL JOB SHOP

EQUIPMENT INVENTORY WORKSHEET #PAGE 2

BLDG ______
AREA ______

SQUAD MEMBERS ______

ITEM NO.	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	B	RR
1	HAND TOOLS IN BOX	SET	H 1' W 2' L 1' DIA		0	2	2
2	RECORDER 24-CHANNEL	2	H 2½' W 1½' L 1½' DIA	FREESTANDING	0	3	2
3	PHOTOGRAPHIC EQUIPMENT	SET	H 1½' W 2' L 1½' DIA	FREESTANDING	0	3	2
4	CABINETS OF MISCELLANEOUS ELECTRONIC TEST EQUIPMENT	3	H 6' W 5' L 1½' DIA	FREESTANDING	0	3	2
5			H W L DIA				
6			H W L DIA				
7			H W L DIA				

DESCRIBE POSSIBLE COLLATERAL DAMAGE

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

#PAGE 2 HARDENING DECISION WORKSHEET

E+RR (A)	BLAST (B)	STRUCTURAL (C)	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER MANPOWER	START COMPLETE	NEW RATING
							X	LOAD ON STAKE TRUCK AND EVACUATE	TRUCK	2 MEN 5 hrs		
							X	LOAD ON STAKE TRUCK AND EVACUATE	TRUCK	2 MEN 5 hrs		
							X	LOAD ON STAKE TRUCK AND EVACUATE	TRUCK	2 MEN 5 hrs		
							X	LOAD ON STAKE TRUCK AND EVACUATE	TRUCK	2 MEN 5 hrs		

← RATING →

PRIORITY = A+B or A+C (lowest sum)

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Relocation Demonstration #2

This manufacturer of large electric switches, etc., is a facility with 15 to 20 employees. The company was involved in planning a move to a new location. Because it was very important to minimize lost production time, this expeditious move provided data on manpower, time, and resources required to evacuate the old site. This information is directly pertinent to a preplanned hardening exercise.

Four men completed the entire move in five working days, which included setting up the new facility. It was estimated that less than eight man-days of this was used to evacuate the old site. Consequently, the entire plant would be moved out in one day, using half the plant personnel and a single forty-foot flatbed truck. Such a vehicle was not available as part of company equipment, but the plant was located next door to two trucking firms with nothing to harden or move other than rolling stock. It is anticipated that a joint effort could be worked out in an emergency.

(Text continues on p. 101)

EQUIPMENT INVENTORY WORKSHEET # 1

BLDG. 1
AREA SHOP

SQUAD MEMBERS JACK

ITEM No.	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE (H / W / L / DIA)	REMARKS	SHUT DOWN TIME	E	KR
1	DRILL PRESS	6		FREE STANDING	0		
2	ROTARY PUNCH	1		FREE STANDING	0		
3	BAND SAW	1		FREE STANDING	0		
4	BENCH DRILL PRESS	3		FREE STANDING	0		
5	LATHE	1		FREE STANDING	0		
6	CABINETS WITH HARDWARE	20		FREE STANDING	0		
7	ANGLE IRON SHEAR	[illegible]		FREE STANDING	0		

DESCRIBE POSSIBLE COLLATERAL DAMAGE
NONE – MOVE ENTIRE PLANT EQUIPMENT TO HOST AREA – 1ST OF 3 PAGES

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

1 HARDENING DECISION WORKSHEET

E+RR	BLAST	STRUCTURAL	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER MANPOWER	START / COMPLETE	NEW RATING
		2					X	EVACUATE	DOLLY/ TRUCK			HOST AREA
		2					X	EVACUATE	DOLLY/ TRUCK			HOST AREA
		2					X	EVACUATE	DOLLY/ TRUCK			HOST AREA
		2					X	EVACUATE	DOLLY/ TRUCK			HOST AREA
		2					X	EVACUATE	DOLLY/ TRUCK			HOST AREA
		2					X	EVACUATE	DOLLY/ TRUCK			HOST AREA
		2					X	EVACUATE	DOLLY/ TRUCK			HOST AREA

← RATING →

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Move-And-Harden Demonstration

This demonstration was conducted in a precast concrete plant in San Jose, California. This was a particularly interesting exercise in that the owner of the plant preferred to conduct the entire operation without technical input from the project team. After reading the manual and going through all the forms, the owner decided the Management Planning Guide; i.e., Booklet # 1, (see Figure 1) provided all the information he needed to develop his own unique hardening and recovery strategy. This strategy was based on a cooperative effort with several other small business entrepreneurs in the area, combining to form an entirely new business operation in the post-attack environment. The hardening strategy included a list of equipment essential to this post-attack business, a hardening procedure, and a novel concept for a hardened shelter onsite, which will be discussed subsequently.

The post-attack business was quite interesting. In its present form the firm produces and erects precast building components such as columns, beams, and wall panels. The owner's analysis indicated that the best immediate post-attack business for his company would not be precast concrete, but salvage, and to this end he would implement a form of mutual aid pact with other local businessmen in the area who were well known to him. These included a trucking firm, a construction firm with both earth-moving and agricultural equipment, and a welding and repair company. This decision aided in the identification of the essential equipment for each of the organizations, which included trucks, forklifts, cranes, tractors, generators, welders, etc.

His hardening strategy was to move equipment to a better location nearby -- in this case, a wide ditch (see Figure 37) on the perimeter of the precast concrete plant. An overall view of the plant can be seen in

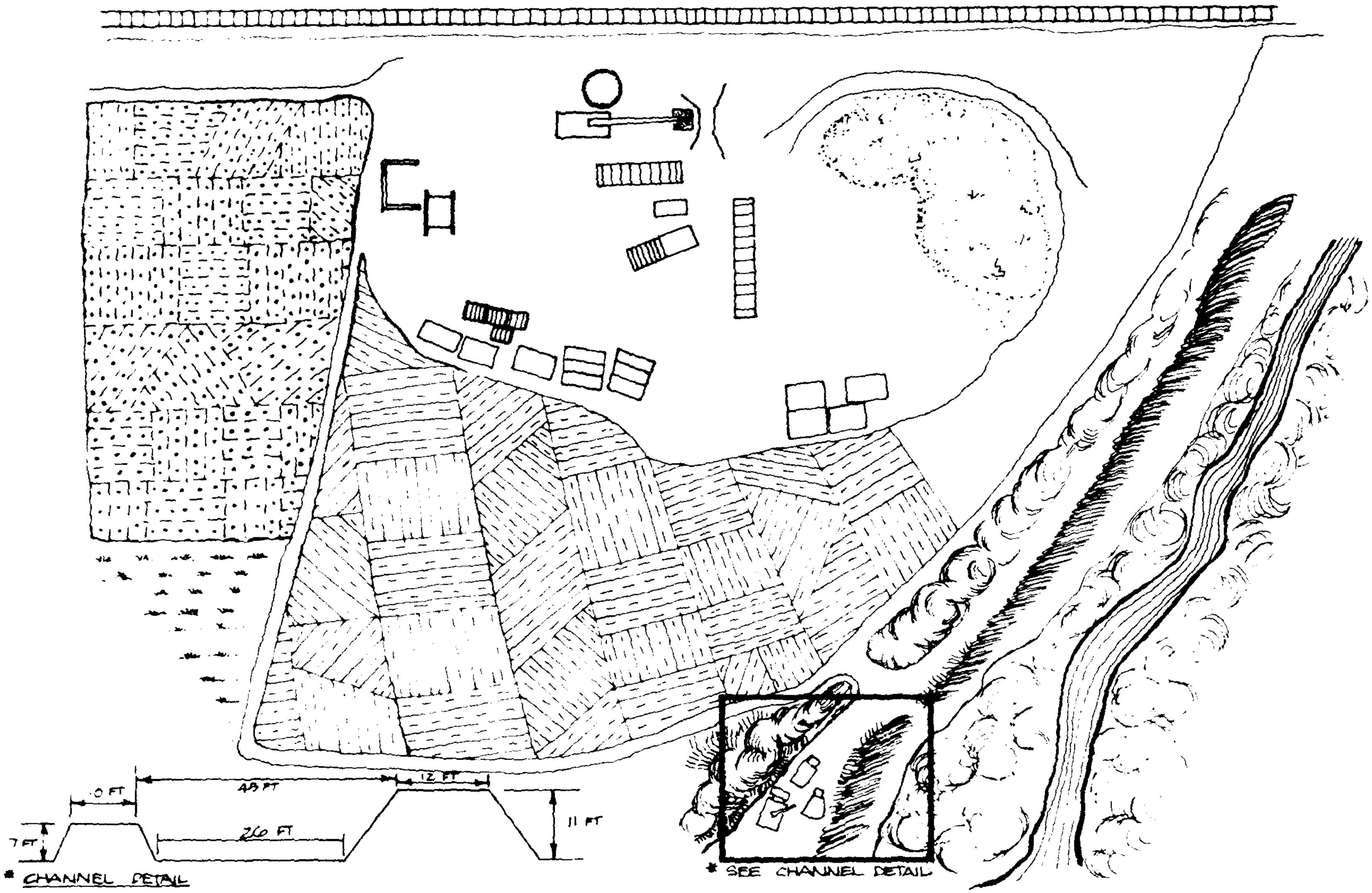

Fig. 37. A Composite View of Plant and Nearby Hardening Site.

Figures 38 and 39. With the aid of a crawler tractor and an endloader from the construction firm, the ditch was cleared of brush (to eliminate fire danger) and leveled (see Figures 40-42). In the event of escalating world tensions, the ditch would be prepared and used as a parking area for all equipment not in use. The rationale was that pressure, *per se*, would not cause much damage to heavy equipment; rather, drag forces, overturning, and missile impact would be the main concern, and the ditch would afford protection. With this strategy, the owner felt that, once prepared, he could assemble his entire complement of post-attack business equipment in the ditch, nights or within one hour after an attack warning.

Another benefit of the strategy selected is that it would provide maximum flexibility for continued operation, whatever the final circumstance that develops. Various views of the equipment installed in this ditch can be seen in Figures 43 through 47. With sufficient warning time, some of the agricultural equipment could also be moved into the ditch, to be used post-attack to cultivate the adjacent fields. This equipment would also be stored in the ditch at night, during periods of high international tension, and be readily available each day.

Another interesting facet of this industry-conducted demonstration was the construction of a key worker shelter on the property. This was accomplished by the acquisition of a prefabricated underground vault (typical of those used by telephone and electric utilities), shown in Figures 48 and 49. A hole was dug by a crawler tractor, the vault assembled including a pipe entrance, and the shelter covered with dirt. This sequence is shown in Figures 50 through 60. It is estimated that, with provision of a blast closure and a ventilation system, this would be an adequate shelter and could probably survive 40 to 80 psi. The construction of the shelter, from the time that the equipment was called in to the time personnel entered the shelter, took less than 10 hours and involved only three men.

As a point of interest, the availability of such shelters was assessed

via a survey conducted in the San Francisco Bay Area. The survey indicated that there are upwards of 100,000 vaults in various manufacturers' stocks or already installed. Vaults of this type, plus manholes and various sewer systems, could make a valuable contribution to key worker protection.

The post-attack business was assessed by the proprietor to withstand 15 psi when hardened. Hardening the entire pre-attack business would, in SSI's assessment, enable it to withstand only 5 psi, if the conveyor and hopper (see Figure 38) were guyed, or 7 psi if these two items were laid on the ground and the hopper filled with material.

(Text continues on p. 125)

Fig. 38. View of Precast Concrete Yard Area from Hardening Site.

Fig. 39. Equipment in Precast Concrete Yard.

Fig. 40. Closeup View of Drainage Channel.

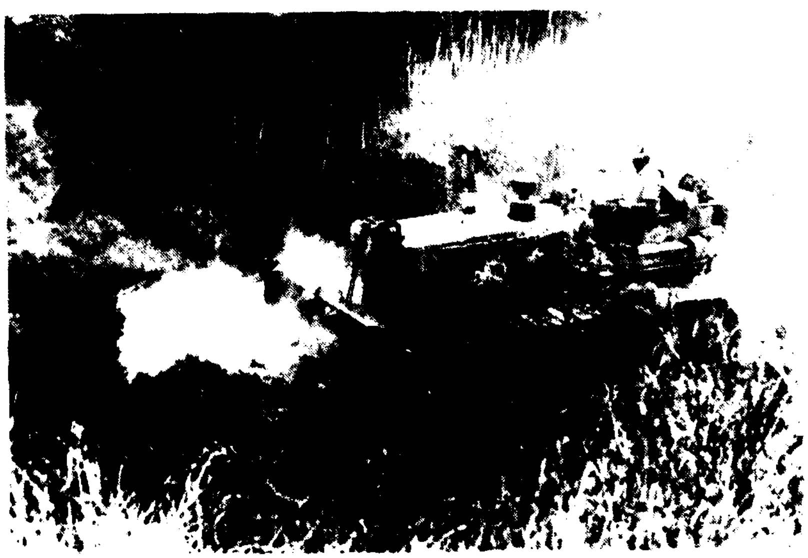

Fig. 41. Cat Clearing Fire Hazard.

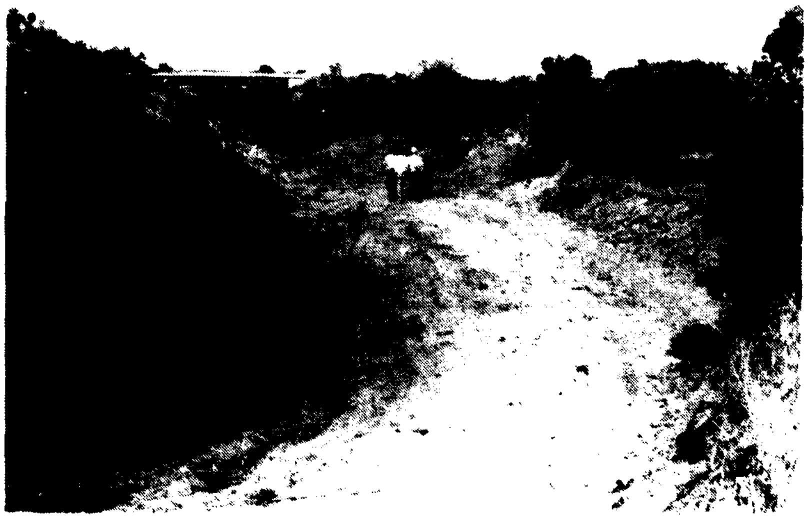

Fig. 42. Cleared Channel.

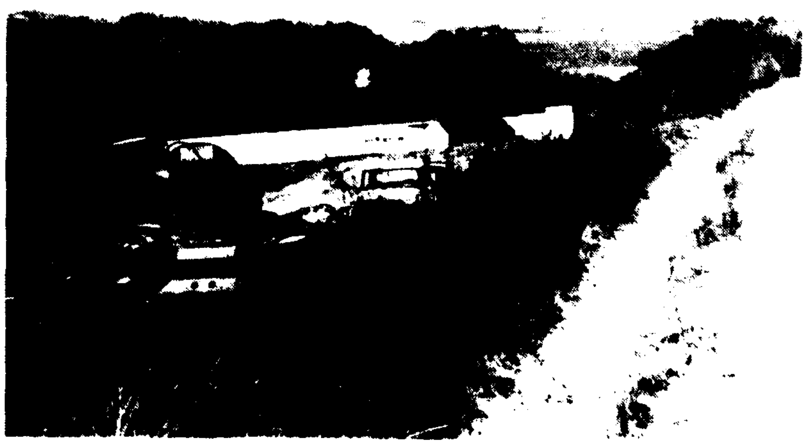

Fig. 43 Mobile Crane, Forklift, Tractor, Pickup in Cleared Channel.

Fig. 44. Tractor and Pickup in Cleared Channel Showing Berm.

Fig. 45. View of Channel, Berm, Forklift, Mobile Crane, Tractor, Pickup, and Welder.

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INDUSTRIAL HARDENING DEMONSTRATION.(U)
SEP 80 J V ZACCOR, C WILTON, G SHEPHARD DCPA01-78-C-0278
UNCLASSIFIED SSI-7828-8 NL

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Fig. 46. View Up Channel With All of Figure 45 Equipment, Flatbed Truck and Crane.

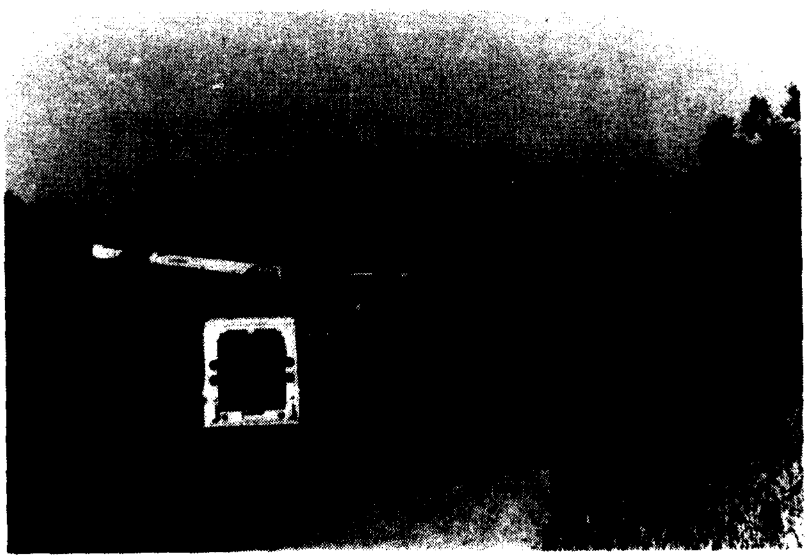

Fig. 47. Final View Up Channel With Semi-Tractor and Van With Generator and Fuel Supply Inside.

Fig. 48. Vault Inventory at Fabrication Plant.

Fig. 49. Vault Center Section.

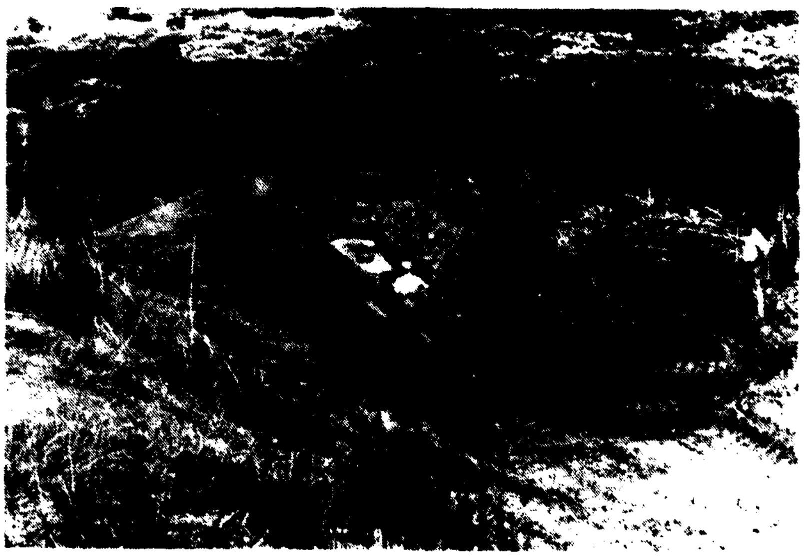

Fig. 50. Cat Digging Hole in Channel for Vault.

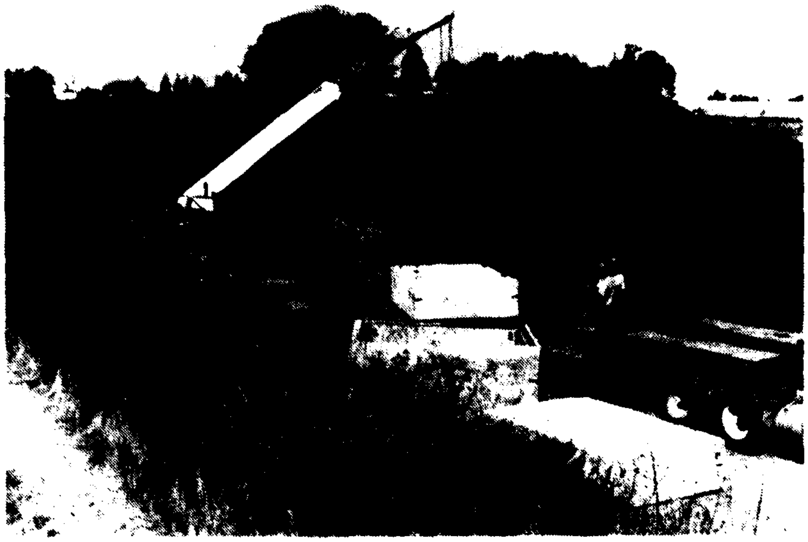

Fig. 51. Vault Offloaded From Flatbed at Channel Site.

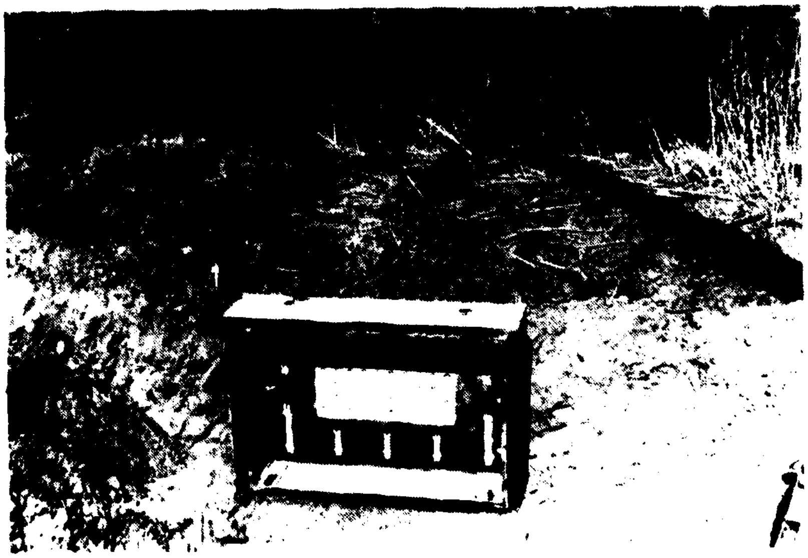

Fig. 52. Vault End Being Placed in Hole.

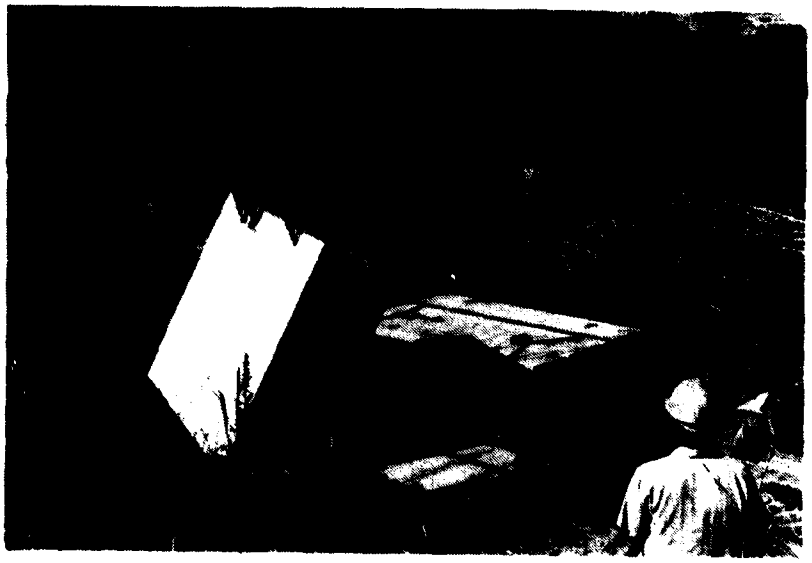

Fig. 53. Opposite End of Vault Being Placed.

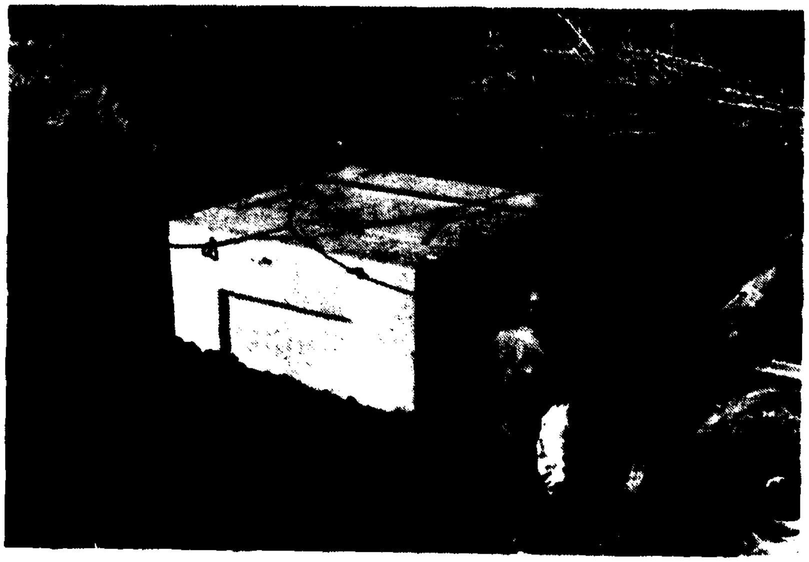

Fig. 54. Completed Vault in Hole.

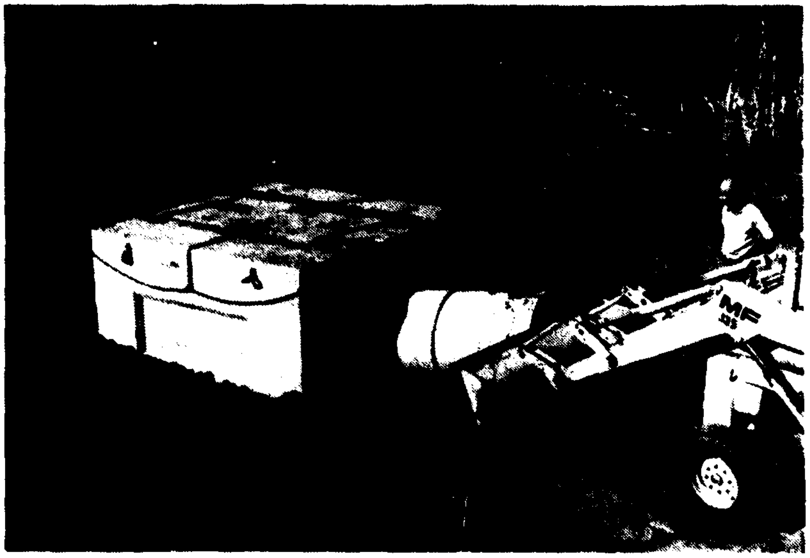

Fig. 55. Vault Entrance Being Placed.

Fig. 56. Commencing Backfilling of Vault.

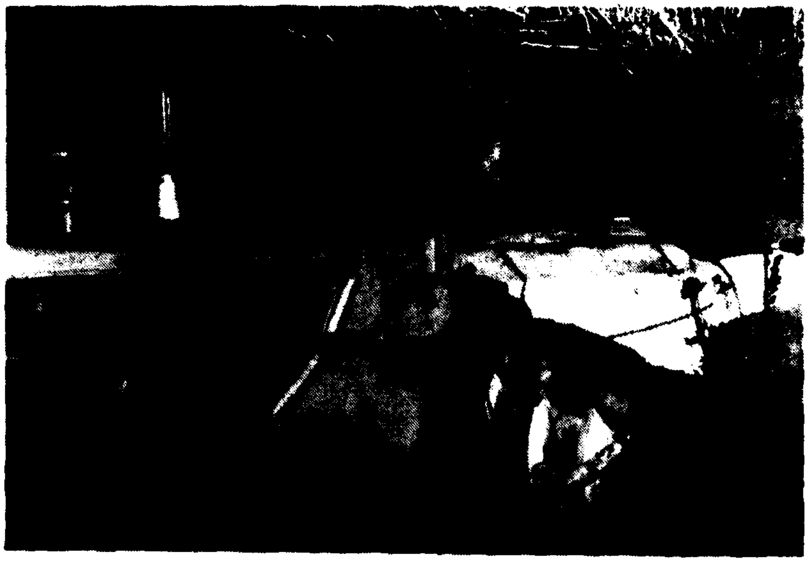

Fig. 57. Backfilling Vault.

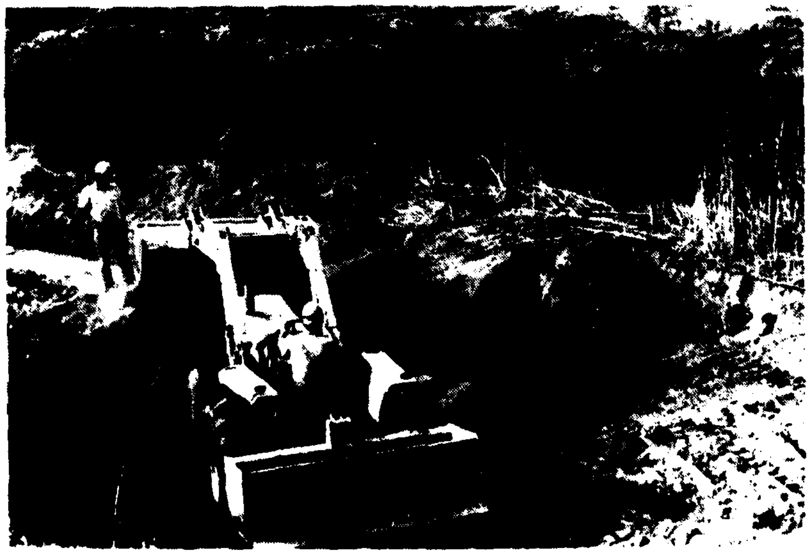

Fig. 58. Final Covering of Vault.

Fig. 59. Entering the Completed Key Worker Shelter.

Fig. 60. Inside the Key Worker Shelter.

PRECAST CONSTRUCTION

EQUIPMENT INVENTORY WORKSHEET PAGE # 1 — PAGE # 1 **HARDENING DECISION WORKSHEET**

BLDG OUTSIDE
AREA
SQUAD MEMBERS
(2) KAMBURGFF

ITEM NO	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR	E+RR A	BLAST B	STRUCTURAL C	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER	[illegible]	[illegible]
1	CONVEYOR - SAND AND AGGREGATE	1	H 100' W 6' L 320' DIA	STARTS IN PIT (CONCRETE LINED) 15 FT BELOW GRADE	0	2	2	4	2	0	6			X		CUT LOOSE AND DROP WELD OR TIE CUT ENDS TO HOPPER FRAME	CUTTING TORCH PRY BARS HAND TOOLS WELDER	JOHN + 2	T+2 / T+4	12
2	HOPPER / MIXER	1	H 100' W 35' L 35' DIA	STANDS ON STRUCTURAL STEEL VERTICAL MEMBERS FED BY CONVEYOR (ABOVE)	0	2	2	4	2	0	6		X			EMPTY HOPPER INTO TRUCKS USE MATERIAL FOR COVER (a) GUY HOPPER OR (b) CUT, DROP, REFILL.	CUTTING TORCHES HAND TOOLS	STEVE + 2		(a) 9 (b) 11
3	STRATOCRANE (POWERED)	1	H 22' W 27' L 30' DIA	MOBILE CARRYALL FOR WALLS & BEAMS, SELF-PROPELLED TOP HEAVY	0	3	2	5	4	0	9		X			DRIVE OVER POURING BED AND GUY TO EACH OTHER (SEE ITEM # 5)	HOIST CABLE GUYS	2 MEN		12
4	CONCRETE TRUCK 8 YARDS	3	H 15' W 12' L 30' DIA	MOBILE MIXER TRUCKS (DIESEL)	0	2	3	5	4	0	9		#1		#2	FILL ONE AND LEAVE HERE FILL TWO WITH ITEMS TO BE EVACUATED AND LEAVE AREA	GAS OR DIESEL FUEL	ONE DRIVER AFTER EVACUATION COMPLETE		15 HOST AREA
5	FORKLIFT 30,000 lb CAPACITY DIESEL	1	H 8' W 8' L 15' DIA	MOBILE/SELF-PROPELLED	0	2	2	4	4	0	8			X		LOAD TO MAXIMUM; DRIVE TO DEPRESSION IN GROUND; LOWER CENTER OF GRAVITY COVER / BERM	MASSEY-FERGUSON TRACTOR FOR PIT	ONE DRIVER OPERATOR	T+1 / T+10	20
6	WELDERS, PORTABLE GAS/ELECTRIC 240 AMP	4	H 5' W 3' L 5' DIA	PORTABLE WITH TRAILER HITCH AND WHEELS GASOLINE ENGINES - D.C GENERATORS	0	2	2	4	4	0	8			X		PUT IN PIT OF CONVEYOR	ONE DRIVER WITH PICKUP	DAVE		20
7	GENERATOR 120/240 7 hp	1	H 1½' W 1' L 3' DIA	PORTABLE, HAND CARRIED (2 MEN) GASOLINE POWERED 4 kW	0	4	2	6	4	0	10				X	EVACUATE FOR USE IN HOST AREA	FUEL FOR EMERGENCY OPERATION	DAVE + 1		HOST AREA

DESCRIBE POSSIBLE COLLATERAL DAMAGE
DAMAGE PROBABLE FROM 100 FT HIGH HOPPER/CONVEYOR SYSTEM; ALSO FROM LARGE AMOUNT OF LOOSE FORM SIDING, FIXTURES, LOOSE MATERIAL IN LOW PILES AND STACKS ALL OVER LARGE AREA (NEXT DOOR TO SCRAP YARD)

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION IF DESIRED

RATING

PRIORITY = A+B or A+C (lowest sum)

PRECAST CONSTRUCTION

EQUIPMENT INVENTORY WORKSHEET # PAGE 2 | # PAGE 2 HARDENING DECISION WORKSHEET

BLDG OUTSIDE

AREA

SQUAD MEMBERS G KANBUROFF

ITEM NO	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR	E+RR A	BLAST B	STRUCTURAL C	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER MANPOWER	START / COMPLETE	NEW RATING
1	OXYGEN AND ACETYLENE TANKS	14	H 5' W L DIA 10"	STANDARD HIGH-PRESSURE BOTTLES	0	2	1	3	10	0	13			X		PUT IN PIT AND EVACUATE: AFTER USE IN HARDENING, PROTECT HALF EVACUATE HALF	FORKLIFT OR HANDTRUCK OR PICKUP	ONE MAN		20 HOST AREA
2	MASSEY-FERGUSON FRONT ENDLOADER/ TRACTOR (MF 330)	1	H 15' W 6' L 12' DIA	TRACTOR WITH FRONT SCOOP/BUCKET LARGE, RIBBED, REAR TIRES	0	3	2	5	4	0	9			X		USE FOR COVERING OTHER ITEMS WITH SAND AND OTHER HARDENING. THEN DRIVE DOWN RAMP INTO PIT	ONE DRIVER	ONE MAN		20
3	MOBILE CRANE 10-TON 30-FT EXTENSION	1	H W L DIA	WHEELED, SELF-PROPELLED VEHICLE	0	3	2	5	4	0	9				X	EVACUATE LAST (SAVE FOR HARDENING TASKS)	ONE DRIVER/ OPERATOR	ONE MAN		HOST AREA
4	BOILER ROOM WITH BOILER CONCRETE BLOCK BLDG	1	H 10' W 10' L 20' DIA	FOR FAST CURING NOT REALLY NECESSARY	1 hr	4	2	6	4	2	8	X				NONE	NONE			—
5	TRANSFORMER - ON OUTSIDE PAD	1	H 4' W 4' L 4' DIA	STEP-DOWN TRANSFORMER ON PAD FOR REDUCTION TO 480 V FEEDS SWITCHGEAR (ABOVE)	0	2	2	4	4	0	8		X			USE FRONT ENDLOADER TO COVER WITH SAND AND REINFORCING WIRE OR CANVAS (SHUT DOWN FIRST)	ONE DRIVER			14
6	AIR COMPRESSOR 50hp WITH RECEIVER IN CONCRETE BLDG. CONCRETE BLOCK TWO SIDES	1	H 10' W 10' L 20' DIA	SOME SUPPLIES ALSO IN BLDG (TOOLS, REPAIR PARTS, etc.)	0	3	2	5	5	2	7		X			SHUT DOWN AND COVER WITH SAND TO PREVENT MOTION.	FRONT ENDLOADER SHOVELS WHEELBARROW			50
7	FLAT-BED TRUCK TRAILER	1	H 4' W 10' L 20' DIA	STANDARD HIGHWAY-TYPE TRUCK TRAILER (UNLOAD) MOVABLE	0	3	3	6	4	0	10		X			EVACUATE		ONE MEN		HOST AREA

DESCRIBE POSSIBLE COLLATERAL DAMAGE

SEE WORKSHEET #1

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

← RATING →

PRIORITY = A+B or A+C (lowest sum)

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PRECAST CONSTRUCTION

EQUIPMENT INVENTORY WORKSHEET # PAGE 3 | PAGE # 3 HARDENING DECISION WORKSHEET

BLDG OUTSIDE
AREA
SQUAD MEMBERS

ITEM NO.	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR	A E+RR	B BLAST	C STRUCTURAL	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER MANHOURS	START / COMPLETED	NEW RATING
1	PICKUP 3/4-TON	3	H W L DIA	STANDARD PICKUP	0	3	3	6	4	0	10				X	USE TO MOVE SPARES AND EQUIPMENT TO HOST AREAS	ONE DRIVER			HOST AREA
2	EQUIPMENT BLDG 20 FT X 10 FT TILT-UP SLABS SECURED WITH BOLTS		H W L DIA	CONTAINS HAND TOOLS FORM HARDWARE, POWER TOOLS	0	4	4	8	2	2	10		X			DROP WALLS BY CUTTING BOLTS AT CORNERS	CUTTING TORCHES OR HACKSAWS OR SOCKETS AND WRENCHES			—
3	MOBILE TRAILERS/ OFFICES	2	H 10' W 10' L 30'-35' DIA	MOBILE HOME-TYPE TRAILERS ON BLOCKS	0	4	3	7	2	2	9	X				REMOVE RECORDS AND EVACUATE LEAVE STRUCTURES	PICKUP OR PRIVATE CAR			—
4	FOREMAN'S OFFICE WOOD		H 12' W 12' L 20' DIA	WOODEN STRUCTURE WITH ONE PARTITION	0	4	3	7	2	2	9	X				REMOVE RECORDS AND EVACUATE	PICKUP OR PRIVATE CAR			—
5			H W L DIA																	
6			H W L DIA																	
7			H W L DIA																	

DESCRIBE POSSIBLE COLLATERAL DAMAGE

COLLATERAL DAMAGE PROBABLE FROM 100-FT HIGH HOPPER AND ASSORTED LOOSE MATERIALS ALL OVER YARD

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

← RATING →

PRIORITY = A+B or A+C (lowest sum)

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PRECAST CONSTRUCTION

EQUIPMENT INVENTORY WORKSHEET # PAGE 1 # PAGE 1 **HARDENING DECISION WORKSHEET**

BLDG. ____________ SQUAD MEMBERS

AREA ____________ IN-PLANT PERSONNEL

ITEM NO.	EQUIPMENT NAME AND DESCRIPTION	QTY	SIZE	REMARKS	SHUT DOWN TIME	E	RR	E+RR	BLAST	STRUCTURAL	PRIORITY	FORGET IT	HARDEN IN PLACE	MOVE AND HARDEN	EVACUATE	HARDENING METHOD	MATERIALS REQUIRED	TEAM LEADER MANPOWER	START COMPLETE	NEW RATING
1	AUSTIN WESTERN M210 ROUGH TERRAIN CRANE, 5-TON CAPACITY APPROX. WEIGHT: 12 TONS	1	H 10'-2" W 8'-0" L 24' DIA	FOUR-WHEEL DRIVE AND STEER SELF PROPELLED, BALLOON TIRES 27-FT BOOM	0±	2	3	5	2	-	7			X		CLEAR CHANNEL BETWEEN TWO LOCAL BERMS; REMOVE BRUSH FIRE HAZARD; PUT BOOM ON BERM; EXTEND OUTRIGGERS MOVE TO HARD SITE	EARTHMOVING EQUIPMENT	BILL AL	T+2 T+7	
2	AUSTIN WESTERN M410 ROUGH TERRAIN CRANE, 10-TON CAPACITY APPROX. WEIGHT: 10 TONS	1	H 10'-6" W 8'-0" L 24' DIA	FOUR-WHEEL DRIVE AND STEER SELF PROPELLED, BALLOON TIRES 45-FT BOOM	0	2	3	5	2	-	7			X		CLEAR CHANNEL BETWEEN TWO LOCAL BERMS; REMOVE BRUSH FIRE HAZARD; PUT BOOM ON BERM; EXTEND OUTRIGGERS MOVE TO HARD SITE	EARTHMOVING EQUIPMENT	BILL AL	T+2 T+7	
3	LINCOLN ARC WELDER APPROX. WEIGHT: 400 lb±	1	H 4' W 4' L 8' DIA	DON'T FORGET ROD PORTABLE (TRAILER) TOWABLE	0	2	3	5	1	-	6			X		MOVE TO HARD SITE (IN CHANNEL); REMOVE COVER PLATES LAY ON GROUND AND COVER WITH SOIL	EARTHMOVING EQUIPMENT	BILL AL	T+2 T+7	
4	ECKO CEMENT MIXER 10 CU. FT. CAPACITY APPROX. WEIGHT: 300 lb±	1	H 4' W 4' L 6' DIA	HAS OWN GAS ENGINE PORTABLE (TOWABLE)	0	3	3	6	2	-	8			X		MOVE TO HARD SITE	EARTHMOVING EQUIPMENT	BILL AL	T+2 T+7	
5	INTERNATIONAL SCOUT II FOUR-WHEEL DRIVE TRUCK APPROX. WEIGHT: 3,400 lb±	1	H 6' W 6' L 16' DIA	FOUR-WHEEL DRIVE HAS CAPACITY TO TRANSPORT UP TO 10 PERSONS	0	2	3	5	2	-	7			X		MOVE TO HARD SITE ROLL DOWN WINDOWS	EARTHMOVING EQUIPMENT	BILL AL	T+2 T+7	
6	PORTA-POWER HYDRAULIC JACKS APPROX. WEIGHT: 20 lb	2	H W L DIA	10,000 lb CAPACITY EACH	0	3	3	6	4	-	10			X		MOVE TO HARD SITE	EARTHMOVING EQUIPMENT	BILL AL	T+2 T+7	
7	GENERATORS 2 EACH 3,000 WATT AND 3,500 WATT APPROX. WEIGHT: 125 lb EA	2	H 1' W 1' L 2' DIA	DON'T FORGET EXTENSION CORDS HAND PORTABLE	0	2	2	4	2	-	6			X		MOVE TO HARD SITE PUT IN CONCRETE BLOCK BOX COVER WITH SOIL	EARTHMOVING EQUIPMENT	BILL AL	T+2 T+7	

DESCRIBE POSSIBLE COLLATERAL DAMAGE

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

← RATING →

PRIORITY = A+B or A+C (lowest sum)

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Section 4
CONCLUSIONS AND RECOMMENDATIONS

The data obtained enable: an estimate to be made of change in vulnerability that can be expected from hardening; evaluation of differences between plant personnel and the originators applying the manual; reasons to be obtained for the performance differences as well as what to do to minimize them; comparisons to be made of how well estimates of the hardening effort (manpower, materials, time) coincided with that actually expended.

Table 2 summarizes the assessments indicating change in vulnerability as a result of hardening. Relocated plants are listed as invulnerable, based on the rationale that relocation will be to a designated host area where overpressures are presumed to be less than 2 psi. The difference between vulnerabilities estimated by SSI and by plant personnel are identified in the table. These were reconciled in the previous section discussion of each plant, and appropriate revisions or additions to the manual to minimize such differences in the future were identified.

Table 3 summarizes the assessments of estimated planning and execution times and manpower requirements for Phase II and compares these with the Phase II results. The two agree fairly well.

The work accomplished, to date, shows the self-help industrial hardening concept to be a feasible and practical strategy. Implementation of the hardening measures by plant personnel have been close enough to estimates to suggest paper exercises can provide a fair appraisal of expected time and manpower cost. In turn, the contribution of such expenditures to industrial survival could be significant in event of a nuclear attack. For example, if all plants could be raised from a vulnerability level of 2 psi (typically, the collapse pressure for the buildings) to 4 psi, then the relative areas

TABLE 2

VULNERABILITY CHANGE DUE TO HARDENING AS AN INCREASE IN OVERPRESSURE EXPECTED BEFORE MODERATE DAMAGE RESULTS TO KEY EQUIPMENT

Plant	Before Hardening (psi)	SSI Assessed Improvement (psi)	In-Plant Personnel Assessed Improvement (psi)	After Hardening (psi)
Metal Caster	2	6	3	8
Electrical Equipment Manufacturer	2	18	—	20
Metal Stamping	2	14	—	16
Steel Fabrication	2	8	—	10
Food Processor	2	invulnerable[a]	—	invulnerable[a]
Utility	?[b]			
Wood Products Manufacturer	2	18	—	20
Small Job Shop	2	invulnerable[c]	(c)	invulnerable[c]
Electronic Equipment Manufacturer	2	invulnerable[c]	—	invulnerable[c]
Precast Construction	2	5	15[d]	17

— Not attempted; SSI assessment only

(a) Mandatory food processing operations of this company all take place in rural areas, and only final "convenience" packaging takes place in this plant. Some of the equipment could be readily salvaged for other uses by other plants, but such analysis was outside the scope of the present study.

(b) Not analyzed or assessed because this utility's resources are already well dispersed geographically.

(c) Moved to host area, where overpressure is presumed to be 2 psi. If host area is not targeted, it may be assumed that these two plants have become "invulnerable".

(d) The proprietor was innovative, deciding to enter a new business in the post-attack environment wherein his most vulnerable equipment would no longer be needed, hence the discrepancy between assessed improvements.

TABLE 3

COMPARISON OF ESTIMATED AND ACTUAL PLANNING AND EXECUTION TIMES

Plant	Planning Effort				Estimated Phase II Effort			Actual Hardening Effort			
	Man-Hours Phase I	Man-Hours Phase II [a]	Number of Men	Elapsed Time (hrs)	Man-Hours	Number of Men	Elapsed Time (hrs)	Man-Hours	Number of Men Used/Avail.	Elapsed Time (hrs)	% of Plant Hardened
Wood Products Company	4	4	2	8	500 [b]	24	36	Staged for movies			20
Small Job Shop	15	1	1	16	12	2	6	14	2/2	7	100
Electric/ Electronics Manufacturer	Unknown				Not estimated [c]			64	8/16	8	100
Precast Concrete Yard	12	3	1	15	16	4	7	24	4/6	10	100

(a) Logistic planning for hardening operations.

(b) One hundred hours if sandbags were filled in advance; forty hours if equipment skidded into a ditch, covered with heavy plastic, and protected with backfill.

(c) Four men required five days to relocate entire plant and return it to full production. It was estimated that evacuation required forty percent of this effort.

subjected to these two overpressures is a measure of damage avoided; that is, the area subjected to 4 psi is only 38% of the area subjected to 2 psi, and the area reaching the new damage level is 62% less than before. If the vulnerability could generally be raised from 2 psi to 8 psi (as appears feasible so far), then the area of damage is reduced by 84% (i.e., to 16% of the original area). If industry were uniformly distributed in the risk area, then according to these calculations, the portion of industry saved from serious damage by hardening (to 4 psi, or to 8 psi) could be 62% and 84% respectively.

The implications are that over 80% of that portion of U.S. industry hardened could be recovered, post-attack, and placed in operation within a short period (perhaps a matter of weeks). Just what portion of a plant or of industry might be hardened is dependent on how successfully priorities are established within each plant and on how many plants, nationwide, respond. Attitudes and decisions about hardening (e.g., the decision at one plant to abandon an old line of business in the post-attack world) will affect the final outcome, and certain capabilities might be in short supply. More preparedness studies involving industry will be required to answer these kinds of questions. One that appears very important to consider at the outset involves the likely circumstance that selected industries would be targeted as an attack strategy to create a bottleneck for the rest.

At the plants visited, all were well aware that disruption of electricity and fuel supplies could negate the benefit achieved by their hardening effort. Some raised the question whether this would not make electric utilities and refineries prime targets. Still, more than half have thought seriously about standby electric power systems as a means to deal with current energy problems and some thought such systems could improve the emergency or post-attack situations. None of these plants had such a system, primarily because they lack the expertise in-house and do not have faith that outside consultants can make better decisions, which are a complex mix of technical, economic, and political factors.

Examining the question of standby units from the opposite end, a supplier of motor generator units provided some interesting information. Questions about standby units have increased fivefold since the winter of 1973-1974 and the average size of interest has increased threefold. There is little doubt that a very strong concern exists for standby power alternatives. It would seem, therefore, that this interest coupled with the new emphasis on cogeneration could provide the impetus throughout the United States to develop a well dispersed backup capability for electric power generation. Moreover, there is no *a priori* reason why these units could not all be installed in easily hardened facilities capable of taking 40 psi or more. If this backup generation capability were to be developed as a serious effort, then a backup fuel supply would become the major difficulty.

The immediate post-attack fuel supply problem is likely to be the loss of refineries. Thus, over the short term, fuel refining in large refineries would probably come to a halt. In this case, whatever refining might be done in the immediate post-attack era would likely have to be accomplished in primitive micro-refineries. Because preparedness planning could greatly enhance this as a workable expedient, a preliminary analysis of this option was conducted to see what the micro-refinery scenario might entail. The analysis has been included as Appendix B.

In summary:

- o Preparedness planning can be expected to enhance survival in a post-attack environment very significantly.
- o A hardening manual has been developed for industry to expedite its self-help planning.
- o The manual has been tested at industrial plants and found workable.
- o With advance planning, hardening can be implemented in one to several days.
- o Improvements to the manual have been recommended, and these

will be studied and appropriate changes made in the future.

- o Industries' dependency on electrical power and fuel is critical.
- o Expedient power and fuel alternatives must be developed, must be obvious to industry to make hardening seem worthwhile, and must not be disruptable.

Testing of hardening concepts needs to be carried beyond testing the feasibility of implementing; field testing should be applied to verify outcomes. Industry needs a repertoire of hardening options that are fully verified for outcome (when implemented by novices!) and described pictorially in the manual. To reduce the amount of field testing required, shock tube studies should be applied to verify analytical methods used to calculate equipment vulnerabilities and to pinpoint the field testing required. Nevertheless, statistical data from a dozen or more tests of a dozen different types of industry are desirable.

To provide a frame of reference for estimating the importance of supporting a serious effort such as described, (perhaps one billion dollars a year) U.S. industry is worth close to one trillion dollars in monetary terms. In terms of world position, this monetary measure is totally inadequate. If the U.S. were to make the choice between losing its world position, or spending a billion dollars, there is little question. We are already spending 150 billion a year to prepare for the common defense. Yet, in the face of a nuclear attack, perhaps the most important facet of U.S. defense is industry, it must survive to supply defense materiel and survival and recovery equipment. The important task of safeguarding industry might be considered worth more than 0.5% - 1% of the defense budget.

APPENDIX A

Encounters With Potential Industrial Hardening Participants

EXAMPLE # 1

"Typical" Encounter With Potential Industrial Hardening Participant

Original appointment made by intermediary with contacts in company. Visitors were C. Wilton, J. Zaccor, Bill Sugg, who met with the owner of a food processing plant.

Started with small talk. Owner told just a little about his company, then launched into a discussion of "60 Minutes" regarding a segment on $16 million loaned, at farm rates, to a multimillionaire.

C. Wilton: Discussed SSI's research into helping industry survive a disaster: earthquake, tornado, hurricane, etc.

Explained SSI compiled a manual that industry can use to develop preparedness plans.

Made point need practical testing of the manual.

Cautioned that manual slanted towards nuclear attack — because started out funded by DCPA, now FEMA . Discussed broader FEMA role; i.e., concerned with any disaster — so SSI attempting to make manual more generalized. Also need to have some of industry try to apply it. Hence, arranging visits to plants where there is an indication of potential interest.

Owner: What do you need/want?

SSI:

a) Permission to go through the plant and make an assessment of vulnerability according to our manual.

b) Pictures, which we will use for our analysis, then return to you for approval of our use in reports.

c) Perhaps a member of your staff could go through several booklets in

the manual — [then gave a quick rundown of booklets]. What we need is someone to speak his thoughts and comments into a recorder that we would leave, along with the manual, for that purpose.

d) Finally, we hope to find several plants willing to go completely through the planning stage and perhaps carry out a dry-run hardening exercise.

Owner: What does that mean?

SSI: Well, it could be anything from carrying out exercises to protect one key piece of machinery to protecting the whole plant. So far, only completely staged tests have been performed — and by experts in weapons effects. What we really need is to find out what can be done by non-experts and how long it takes.

Owner: Well, I guess my son could show you around the plant. You can take pictures if you want. Let me get Tony.

SSI: What we'd like to do is sort of start where the product comes into the plant and follow it through — then get a feel for how to protect key equipment.

Tony: Well, if you walk over here I can show you how it all starts. We get (right now, tomatoes) for processing, whatever — depends on the seasons, etc. Anyway, it comes in here in trucks — you ever see them on the road in the valley? — loaded with tomatoes. Well, they bring 'em right up here and they are dumped in there and . . . . Then, if you come over here, ... Then they go . . . to get . . . . etc.

SSI: Is there anything in this process line that you could do without?

Tony: Well, I don't think we could do without any of it — or we wouldn't have it. It's all important to our operations.

SSI: Well, suppose there were an emergency or something: Say, the equipment got damaged, what do you do; that is, how do you handle it?

Tony: That depends on what the damage is — For example we can call up at a moment's notice and expect to get a 100-horsepower boiler onsite and operating within 8 hours.

SSI: Well, we were thinking of maybe a fairly large-scale disaster — where the whole state is affected, or maybe even the entire United States, like with a nuclear attack. If that were the case, is there anything here you could maybe do without? — so that you could concentrate on trying to save just a few really important items?

Tony: Um, gee — a nuclear war? I guess everybody is affected — Yeah, we wouldn't need anything here then. We could do without all of it. People would be hungry, then. What would they care about whether the cores were removed — or the skin taken off? You see, all we do here is sort of cosmetics. We make it attractive on the table — and most of what we do is condiments, with probably almost no nutritional value. People will need the basics, not condiments. Now, we could pasteurize milk instead of processing tomatoes, and we could can more nutritional things like fruits instead of condiments. All that stuff there — you know where I showed you the tomato trucks come in — we still wouldn't need any of it. Who would care about skin being on the fruit? No. The heart of what would be needed are the evaporators and the canning line; all the rest of it could go. We probably need the conveyors here, though — to get the stuff from the evaporator to final packaging.

SSI: Well, one of the things that will happen is that a lot of people won't have work because their plant is gone — so there might be plenty of manual labor available with nothing better to do than preserve food.

Tony: Yeah, that's probably so — I hadn't thought of that. I expect just about everything would be different.

SSI: You seem to have lots of cans — You could convert some to pails; couldn't people move stuff around in pails?

Tony: Sure, that's probably easy enough to arrange if you have the people and they are willing. I guess anybody would probably be willing if it meant the difference between getting fed or not — even if it's just apples.

SSI: Well, you seem to have the idea of what we need to consider all right. Do you think you could look at this manual we have made up and

see if you can follow it — what questions come to mind; how you might do it differently — things like that?

Tony: I could, but we're into the heavy tomato season now and there isn't much time for it. I couldn't get to it for quite a while.

SSI: Well, we know it is time-consuming and we are hoping that we can uncover enough immediate benefits in the way of advance planning for just about any emergency to make it worthwhile — but to do that we are going to need people to review it and give us back some ideas. Because that takes time, we are willing to pay whoever does it for their effort.

Tony: I wouldn't mind doing it, but canning is seasonal and when it's on it pretty well takes all the time there is.

SSI: Could we leave the manual and ask you to work it in when you get a chance?

Tony: Well, I suppose so. The thing is, I couldn't promise you when that might be.

SSI: That is understandable. We'll leave you this copy and then when you do have some time, it will be handy.

EXAMPLE # 2

Commentary on Crisis Relocation Industrial Hardening Plan
Taped by Electronics Plant Manager

Booklet No. 1

My overall impression, as a manager of a business, to Booklet No. 1 is that more effort should be made to put the business that is being addressed in perspective to the total problem. For example, the first thing I want to know is whether or not I would be a critical industry. The next thing is in what area is my plant located — am I in a high-risk or a low-risk (host) area? Setting the context for a manager reading this material is very important; otherwise it all seems very overwhelming and almost unrealistic to consider that all of this hardening could be done in a 72-hour warning period.

The next thing I would want to know is how I would go about implementing or even thinking about the management planning required for a hardening program. I realize that the Booklets 2 through 10 or so answer this question, but an overview of the process would be important in the first part to give me a feeling that it is actually "do-able". The six drawings at the end of Booklet No. 1 depicting the different ways to protect against blast of different magnitudes are very interesting to me as a former engineer; introduced this early in the information tends to make me believe the whole thing is unrealistic. I can't imagine putting in shore posts if it's actually only a 72-hour warning; on the other hand I can't imagine putting in shore posts right now on the assumption that some day we'll have an emergency.

Booklet No. 2

Since this is my first exposure to this entire concept, I find Booklet No. 2 rather mind-boggling. First, it involves an apparent degree of responsibility for the dependents of all of the work force that I would not

have thought practical for a 300-man company. For purposes of studying a possible relocation, our company had actually generated a map with pins designating employee home locations. Our plant was located, as you might expect, in the center of the distribution of the employees' homes. We had employees who lived in every direction from the plant and commuted typically 30 minutes and in many cases one to one and a half hours. In our specific case, we had employees living in San Francisco, Santa Cruz, Gilroy, Fremont, and Berkeley, with our plant located in Mountain View. It is hard for me to imagine how it would be practical to evacuate. . . .

The general approach outline started on page 3 of Booklet No. 2 strikes me initially as a little complex to carry out under the deadline of a 72-hour evacuation notice. It might have to be simplified to something like having everyone who lives in Redwood City gather in the left-hand corner of the plant and work out a plan for themselves. Also, it seems to me that it is important whether the plant is essential or non-essential in that, if it is non-essential and is going to be shut down, there would be no need to try to move all of the dependents into one place. Rather, the facility would be shut down and people would be free to leave and take care of their families under Civil Defense instructions.

The other question that comes to my mind is how does my company pick its host area?

Booklet No. 3

Page 5, Item 3.— It should be more specific exactly what the crews that are being sent out are to accomplish. I assume they are to do the work outlined on the right-hand side of page 2 and the top of page 3.

Page 7. — Under decision factors, it mentions again that vital records can be moved from the risk to the host area, but so far I haven't the foggiest idea of what my host area is, or how I would go about figuring out what my host area is supposed to be.

Booklet No. 4

It seems to me that the teams sent out for resource inventory could somehow be combined with the teams sent out to perform the work outlined on page 5 in Booklet No. 3. The resource inventory might even come before the work parties go around trying to conduct protective housekeeping activities. In the time frame talked about, I don't see how you can have time for teams for resource inventory and filling out those forms, and also work parties for protective hardening and filling out the forms at the end of that booklet.

Booklet No. 5

My reaction is it's far too complex. If it wasn't done in advance, there would be no way to get the people to fill out that kind of detailed inventory in a one or two hour period when they have just received a 72-hour notice to evacuate.

My overall reaction to reading all of the booklets is that the plan does not seem realistic to implement under a 72-hour deadline. The forms are too complicated for the time period involved. I have a lot more comments and thoughts on the subject, but I'd like to go over them in person, because I'm running out of tape.

EXAMPLE # 3

Commentary of Proprietor at Precast Concrete Plant Participating in Phase II

Booklet No. 1

After reading through the whole manual twice, I believe I would throw all the booklets excepting Booklet No. 1 away. I got the picture clearly from this management booklet, while the rest just consumed time and did not add enough for me to really warrant spending it.

Booklet No. 2

I automatically think of those people that I believe would make all the difference to survival — and they are the ones that would also help establish an operating company under whatever conditions turn up. We're small, but we could set up to handle 60% of our crew and their entire families. I have property in a good safe area, and chances are that with advance notice we might all relocate there.

Booklet No. 3

I wouldn't bother with protective housekeeping — I'd just move what I wanted to protect out to a place where that isn't a problem; it would be a hell of a lot faster. I'd guess we could do it in an hour if we were prepared, whereas it would take days to clean up around here.

Who needs records? Who is going to be in a position to pay old bills anyway? No, I'd start from a clean slate and move faster than the old conservatives, probably wind up owning a piece of their action as a result of bailing them out. I wouldn't do it for money because what would that be worth? Who would be using it? Not me! Barter and equity are the only way to go.

Booklets No. 4 to 8

I know what I need and I know I don't need complicated schemes like these to tell me. It's all pretty simple if you read Booklet No. 1, and part will be luck anyway. I can do everything that has to be done in one day and I can keep right on operating after it's set up. I'll have everything hardened when not in use, and one hour is all I need to respond at any time. My site is located only a few hundred yards from the intersection of two major highways, one an interstate, so that when it's over I can get most anywhere I might be needed in a hurry.

APPENDIX A SUMMARY

When you read these responses it appears that the viewpoints are poles apart, an indication that attitudes and opinions make up the major reason for differences — not necessarily the manual. There is no doubt that the manual can be improved by incorporating a great many of the suggestions made, but, of course, when the suggestions are diametrically opposed this is not feasible.

The comments in this appendix show also that there is a great deal of innovative talent that will come to the fore when needed. Acceptance, a will to take action, and an ability to relate to different circumstances seem to lie at the heart of this innovative response.

APPENDIX B

Post-Attack Petroleum Refining
(and Production) from Crude Oil

POST-ATTACK PETROLEUM REFINING (AND PRODUCTION) FROM CRUDE OIL

BRIEF HISTORY

Petroleum refining began in the United States and Russia in the second half of the 19th century, following the discovery of "rock oil" in Pennsylvania in 1859. In the earliest refineries, simple stills separated crude oil into impure gasoline, kerosene, lubricating oil, and fuel oil fractions. The first big advance in petroleum production technology came in 1913 with the introduction of thermal cracking. This process consisted of taking the heavier fractions after distillation and heating them under pressure, thereby cracking, or splitting, their large molecules into the smaller ones that form the light, more valuable fractions. During the 1930's and World War II, refining processes involving the use of catalysts led to further improvements in the quality of fuels and increased their supply. These included catalytic cracking, polymerization, alkylation, and isomerization. The 1950's and 1960's brought a large-scale demand for jet fuel and for high-quality lubricating oils. Catalytic reforming was established as the leading process for upgrading automotive motor gasolines for use in the higher compression engines. Hydrocracking, accomplished by the addition of hydrogen during refining, also improved the crude-oil fractions.

TYPES OF CRUDE

Crude oils vary widely in boiling range and composition. Fig. B-1 shows the proportions of the products obtained by distillation of six typical crude oils, ranging from West Venezuelan heavy crude to the light Algerian crude, Hassi-Messaoud. The percentage of lighter products (gasoline and naphtha) increases to the right of the chart. Middle distillates (which include kerosene and diesel) also increase, while fuel-oil content diminishes.

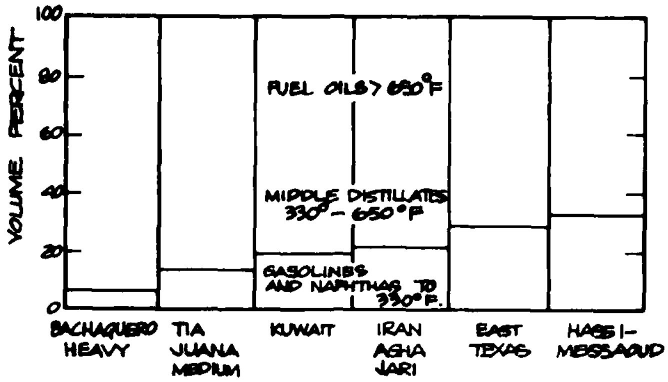

Fig. B-1. Proportions of the products obtained by distillation of six crude oils.

Four main types of hydrocarbons are present in crude oil: normal paraffins, isoparaffins, cycloparaffins (also called naphthenes), and aromatics. Some crude oils, such as Pennsylvanian, consist mainly of paraffins. Others, such as the heavy Mexican and Venezuelan crudes, are predominantly naphthenic and are rich in asphalt. The various hydrocarbon compounds that are mixed together in crude oil have different boiling points, but apart from the lightest, the differences between the boiling points of neighboring members in the rising scale of molecular weight are so small (only fractions of a degree) that they cannot be separated by ordinary distillation. Fortunately, separating is not usually necessary; most common petroleum products consist of mixtures of compounds where boiling points fall within a specified range.

Typical boiling ranges (at 1 atmosphere) are:

motor gasoline:	75° - 300°F (25° - 150°C)
kerosene:	300° - 450°F (150° - 230°C)
diesel oils:	450° - 650°F (230° - 340°C)
fuel oils:	above 650°F (340°C)

STATE-OF-THE-ART TECHNOLOGY

A generalized flow chart of a modern refinery process is shown in Fig. B-2 below.

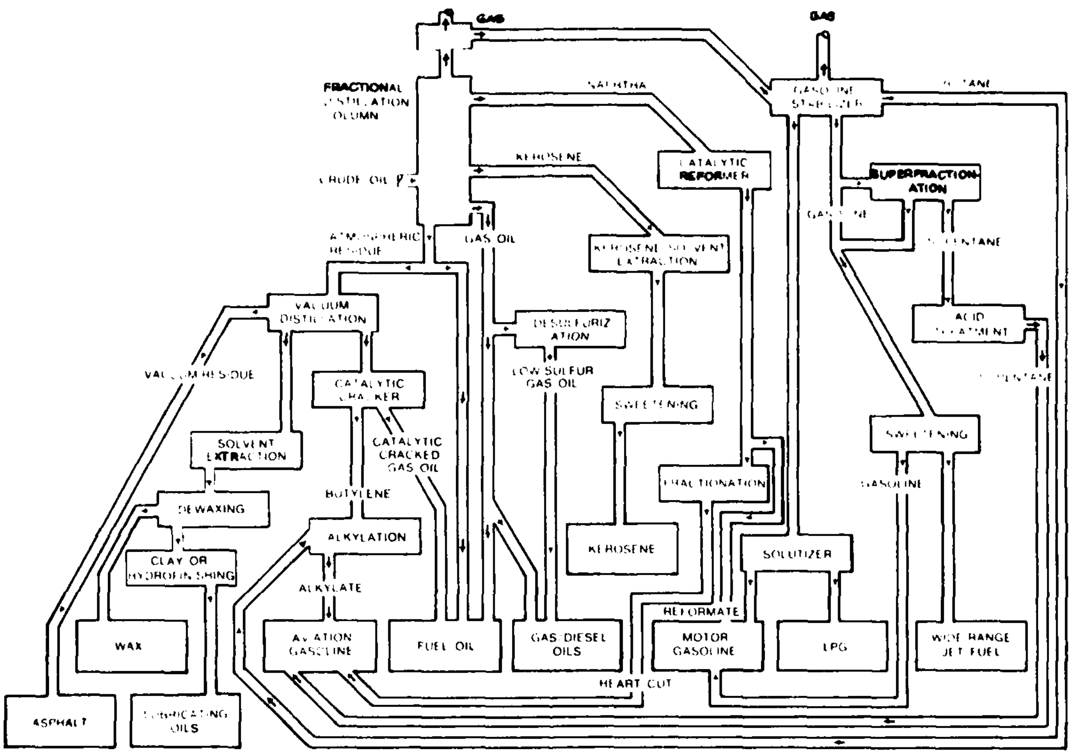

Fig. B-2. Generalized flow chart of the refinery process.

The technology involved can be broken down into the following major components:

Separation Into Components

The primary refinery process is fractional distillation; this unit is mainly a rectifying column from which a number of side-stream products are withdrawn as well as overhead and bottoms: an overhead gas product and light gasoline liquid overhead product at about 245°F; a heavy gasoline side stream at about 300°F; a kerosene side stream at about 380°F; a gas

oil distillate side stream at about 540°F; and a bottoms product at about 600°F. Fig. B-3 shows a fractional distillation unit.

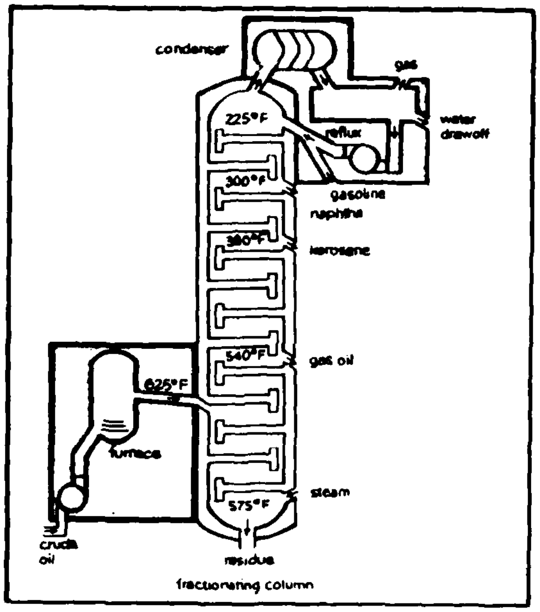

Fig. B-3. General operating principles of a fractional distillation unit.

Vacuum distillation resembles fractional distillation, except that larger diameter columns are used to maintain comparable vapor velocities at the reduced pressures; the equipment is similar.

Superfractionation is an extension of fractional distillation employing columns with a much larger number of trays (e.g., 100) and reflux ratios exceeding 5:1.

Absorption and stripping are processes used to obtain valuable light products such as propane/propylene and butane/butylene from the gas vapors that pass out of the top of the fractionating tower.

Solvent extraction processes are used primarily for the removal of constituents that would have an adverse effect on the performance of the product in use.

Adsorption. Silica gel is used to separate aromatics from other hydrocarbons, and activated charcoal is used to remove liquid components from gases.

Alterations of Molecular Structure

By changing the molecular structure of the components of crude oil, it is possible to convert less valuable hydrocarbon compounds into those in demand.

Thermal cracking is typified by processes in which kerosene or gas oil materials are converted by heating to 850° - 1000°F (450° - 540°C) at pressures of 250 to 500 psi. This produces gasoline of about 70 octane number.

Thermal reforming alters the properties of low-grade components such as naphthas by converting the molecules into those of higher octane number (and therefore lower molecular weight).

Use of a catalyst in the cracking reaction increases the yield of improved quality products under much less severe conditions than thermal cracking (850° - 950°F and 10 to 20 psi). Zeolitic or molecular sieve-base catalysts are used.

Catalytic reforming uses catalysts to mold molecular structure into desirable forms without the formation of unwanted heavy products and coke.

In polymerization gaseous hydrocarbon molecules are induced to combine, or polymerize, into molecules of two or more times the molecular weight, forming a material that performs well as a motor fuel.

The alkylation reaction also achieves a longer chain molecule by the combination of two smaller molecules, one being an olefin and the other an isoparaffin.

Isomerization converts the more abundant normal butane into isobutane as well as pentane and hexane into the corresponding isoparaffins.

Hydrocracking is used for producing gasoline or middle distillates from heavy gas oils, for converting residues into lighter oils, or for producing liquefied petroleum gases from straight-run naphthas. By cracking these in the presence of hydrogen and a catalyst, valuable products are obtained without simultaneous formation of coke and large quantities of gas.

Purification Processes

Sulfuric acid treatment removes sulfur by dissolution, polymerizes highly reactive hydrocarbons and neutralizes nitrogen bases. Asphaltic constituents and easily oxidizable compounds are also removed.

Sweetening processes convert evil-smelling and corrosive mercaptans into relatively innocuous disulfides.

Hydrotreatment processes are used primarily for sulfur removal from gasolines, naphthas, kerosenes, and diesel oils.

POST-ATTACK PROCESSES

Several simplified processes for petroleum distillation in a post-attack recovery scenario can be devised. A few of these are described here.

1. Simple Batch Distillation

This is a distillation process in which a batch of material is charged to a still, vaporization is caused by the suitable application of heat, and the vapors are removed continuously, as formed, with no partial condensation of the vapors or refluxing of condensate to the still. Fig. B-4 presents a schematic flow sheet of the process.

The still (distillation pot) can be made from practically any large vessel used in industry, examples being railroad cars, LNG storage tanks,

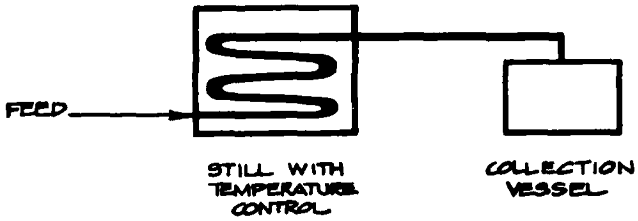

Fig. B-4. Schematic flow sheet of batch distillation.

autoclaves used in laminated glass production, reaction vessels used in the chemical industry, etc. These should be thick-walled (more than 1/4-in. thick) and preferably of stainless steel construction with a large surface-to-volume ratio, in order to increase the heating efficiency. Care should be taken to make sure that the still is accessible to humans for removal of the residues. From this point of view, a cylindrical autoclave with a side door would probably be most desirable.

The temperatures required are easily achieved with wood fires. Alternative sources of heat available are the light fractions (butane, propane, pentane) and the residues left in the distillation still. When using fuels for direct heating, due care must be given to safety. Inattention can cause the flames to light the feed, or any one or more of the products. Spilled petroleum must be thoroughly cleaned up at all times. A full description of the safety aspects of direct-flame heating will be deferred to a more detailed study.

The collector vessel can be improvised from practically anything that will not be dissolved by the liquid fractions; e.g. 55-gallon drums, dumpsters, reactor vessels. Tank cars might prove to be ideal since they are already on wheels, and can be conveniently changed for collection of different distillates.

Pipe connections between the still and collector vessel should be at least 4 in. in diameter, and preferably larger. Condenser coils can be

made from copper tubing. This should preferably be wound in several sections, with a valve to adjust the flow rates so that the cooling rate can be adjusted according to the distillate to be collected.

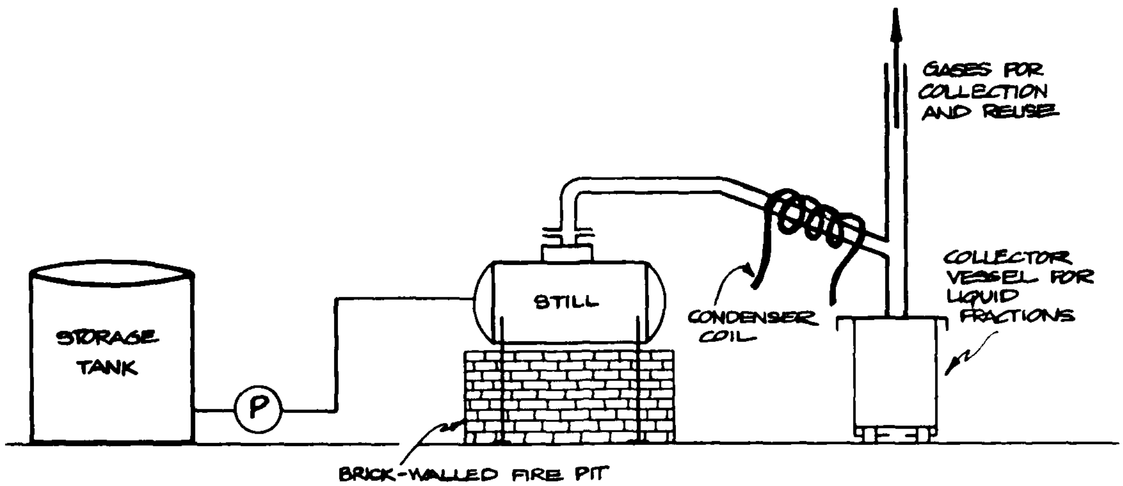

Fig. B-5. Simplified process diagram for batch distillation.

The evaporation rate of the desired fractions will be dependent on

(1) Heat transfer from flame (fire pit) to crude in distillation pot,

(2) Partial pressure of distillate,

(3) Type and composition of crude,

(4) Operation pressure (assumed atmospheric),

(5) Surface area of crude in the distillation pot.

Sample Calculation. — A detailed discussion of batch distillation calculations is beyond the scope of this work. However, a simplified calculation scheme using the Rayleigh Equation is illustrated here. This calculation scheme is suited to differential vaporization and is based on the relative volatilities of the components.

Let A, B, C, D, etc. represent the total moles of the respective components in a multicomponent mixture. If a differential amount of the

mixture is vaporized:

$$\frac{-dA}{dB} = \frac{y_A}{y_B} = \alpha \frac{x_A}{x_B} \qquad \text{(Eq 1)}$$

where x is the mole fraction (or weight fraction) of the more volatile component in the liquid, and y is the mole fraction (or weight fraction) of the same component in the vapor in equilibrium with the original liquid. α is a constant which is normally independent of temperature.

$$x_A = \frac{A}{A+B+C+D} \qquad x_B = \frac{B}{A+B+C+D} \qquad \text{(Eq 2)}$$

Therefore:

$$\frac{-dA}{dB} = \alpha \frac{A}{B} \qquad \text{(Eq 3)}$$

Integrating

$$\ln \frac{A_1}{A_2} = \alpha \ln \frac{B_1}{B_2} \qquad \text{(Eq 4)}$$

where A_1 = total moles (or weight) of component A in the original mixture

A_2 = total moles (or weight) of component A remaining in the residual liquid after the batch-distillation operation

B_1 = total moles (or weight) of component B in the original mixture

B_2 = total moles (or weight) of component B remaining in the residual liquid after the batch-distillation operation.

The variation of α under the conditions of the distillation should be investigated before applying Equation 4.

The mixture of fractions assumed in the crude is shown in Table B-1. This is similar to some compositions of Texas crude. Average molecular weights based on average boiling points of gasoline, kerosene, and diesel have been assumed, and are shown in Table B-2 and Fig. B-6.

Table B-1: Assumed mixture of fractions

Fraction	Weight (%)
Gasoline	16
Kerosene	33
Diesel	14
Residue	37

Table B-2: Average boiling points and molecular weights

Fraction	Boiling Point Range (°F)	Average Boiling Point (°F)	API Gravity	Average Molecular Wt.
Gasoline	75 - 300	187°F	70 - 52	85
Kerosene	300 - 450	375°F	52 - 40	160
Diesel	450 - 650	550°F	40 - 30	240
Residue	> 650			310

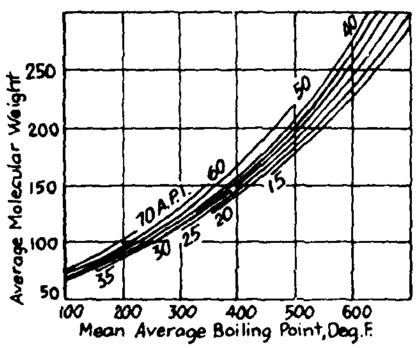

Fig. B-6. Molecular weights of petroleum fractions as a function of boiling point and specific gravity.

On the basis of 100 kg of the original mixture, the initial calculation is done for distilling out gasoline. Similar calculations can be repeated for the kerosene and diesel fractions. An initial distillation temperature of 220°F is assumed, with the final temperature (at condensation) at 70°F. The vapor pressures have been estimated with Fig. B-7, and are tabulated in Table B-3.

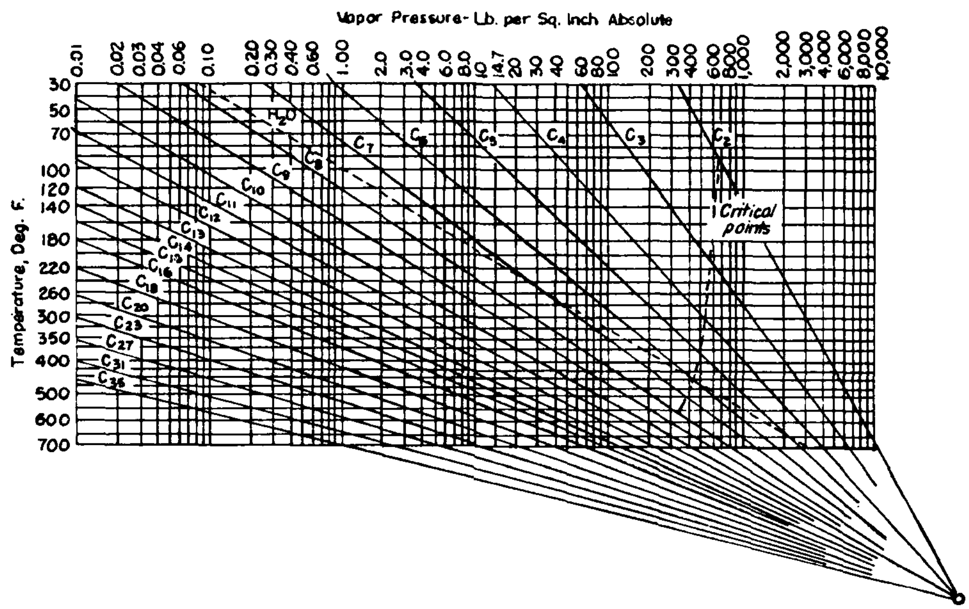

Fig. B-7. Cox chart for vapor pressures of normal paraffin hydrocarbons.

Table B-3: Vapor pressures of the fractions at 220°F and 70°F

		Gasoline	Kerosene	Diesel	Residue
Weight (%)		16	33	14	37
Average Molecular Wt.		85	160	240	310
Moles		0.188	0.206	0.058	0.119
Mole Fraction		0.329	0.361	0.102	0.208
Vapor Pressure at 220°F	psi	42	0.9	0.02	0.001
	mm Hg	2171	46.5	1.03	0.1
Partial Pressure mm Hg		714	16.8	0.11	0.01
Vapor Pressure at 70°F	psi	2.7	0.01	--	--
	mm Hg	139.6	0.52	--	--

$$\text{For} \quad \frac{C_{gasoline}}{C_{kerosene}}: \quad \alpha_{220} = \frac{46.5}{2171} = 0.0214$$

$$\alpha_{70} = \frac{0.52}{139.6} = 0.0037$$

$$\alpha_{avg} = 0.0126$$

Assuming that 90% of the kerosene is to be left in the distillation pot (i.e., 10% goes over with the distillate), and using Equation 4:

$$\log \frac{\text{Initial kerosene}}{\text{Final kerosene}} = 0.0126 \log \frac{\text{Initial gasoline}}{\text{Final gasoline}} \; *$$

$$\log \frac{33}{29.7} = 0.0126 \log \frac{16}{x}$$

$$\log \frac{16}{x} = (\log \frac{33}{29.7}) / \; 0.0126 = 3.6315$$

$$x = 16/10^{3.6315} = 0.0037 \text{ kg}$$

Therefore, percentage of gasoline left in liquid = (0.0037/16) x 100 = 0.02%

If 95% of the kerosene is to be left, then a reiteration of the above calculation yields: 0.02730 kg gasoline left in the liquid. This is equivalent to 1.7%.

The yield of gasoline is above 95%. But one must be warned that these calculations are extremely simplified, and that crude fractions could change quite a bit from region to region.

2. Continuous Distillation

Batch distillation is the simplest of installations. The next step is the arrangement of such a still for continuous or semi-continuous operation. The first step to take would be to increase the distillation temperature

---

* Note: The natural logarithm (ln) of Eq 4 has been converted to logarithm of base 10 (log) for ease of handling.

to around 600°F, and increase the number of collection vessels from one to three for the gasoline, kerosene, and diesel fractions. A schematic flow chart of such a process is shown in Fig. B-8.

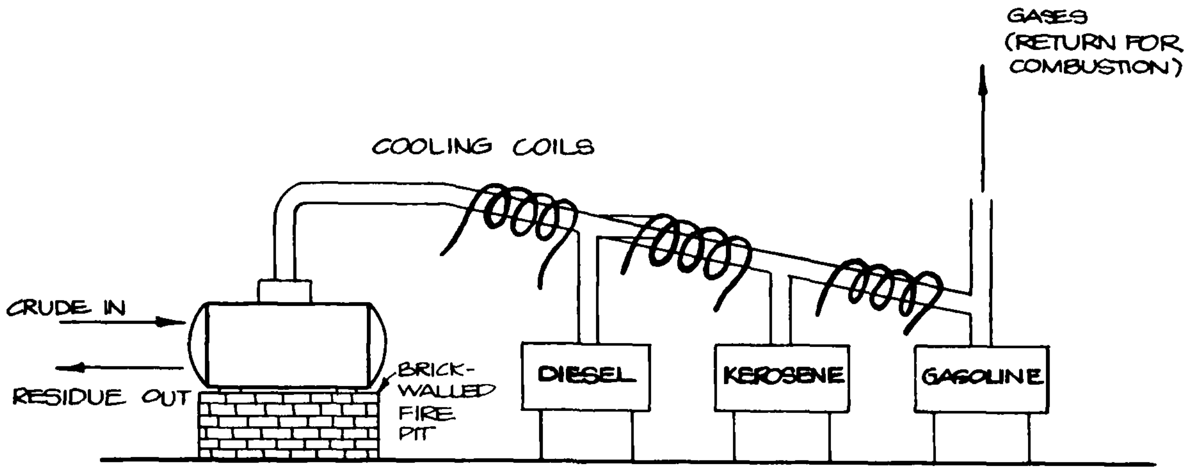

Fig. B-8. Schematic of continuous distillation.

The vapors will be cooled in sections to permit the condensation of the fractions one at a time. The gaseous and residue fractions can be used for heating of the crude. A sophistication to this process can be added by using the raw crude to cool the vapors, the crude becoming heated in the process. This can be achieved by using conventional pipe heat exchangers arranged suitably. Auxiliary cooling with water might be required. As the volume of production increases, the cooling rate achievable with cooling coils will be limited, and the transition to heat exchanger type condensers cannot be avoided. The use of several truck radiators is also conceivable. Compared to batch distillation, more condensers and piping are required. The same distillation still could be used.

Semi-continuous operation of such a unit calls for raising the temperature gradually, and collecting the respective fractions. The still will then have to be emptied and recharged.

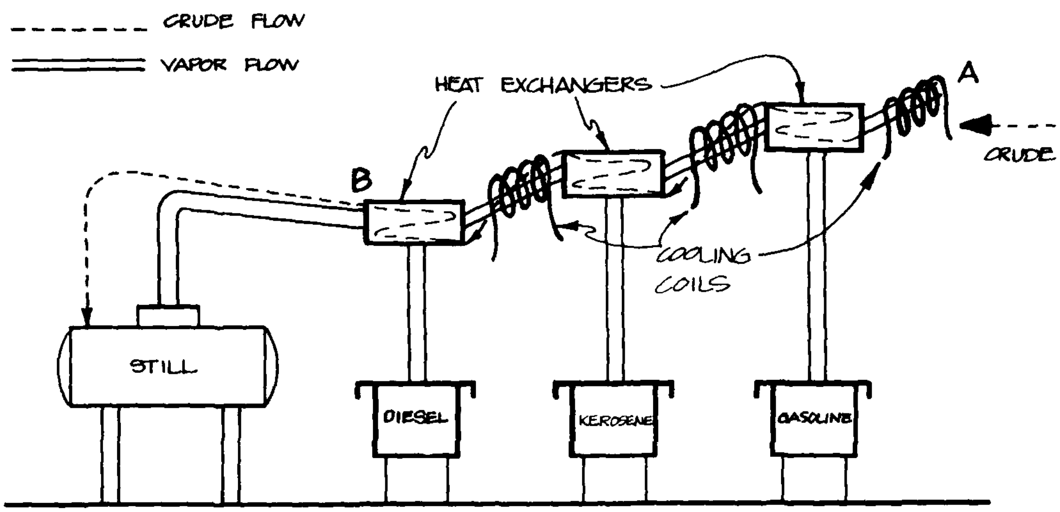

Fig. B-9. Continuous distillation using heat exchangers for condensing vapors and heating crude.

3. <u>Continuous Distillation with Fractionating Tower</u>

Distillation may be so conducted that fractionation of products results to a greater or lesser degree, but complete separation of several products from one liquid by one distillation is impossible without auxiliary fractionating equipment. A schematic flow diagram of a distillation still with fractionating tower is shown in Fig. B-10.

An ideal installation that could be modified for fractionating could be a boiler with its stack. The inside of the stack will have to be lined, and trays installed for the fractionation. The space between the trays should preferably be filled with perforated sheets (because of their light weight) or some other suitable material to promote nucleation of the vapors. Holes will have to be made in the side wall for extraction of the condensed fractions. The boiler can be modified into a pipe still for heating the crude.

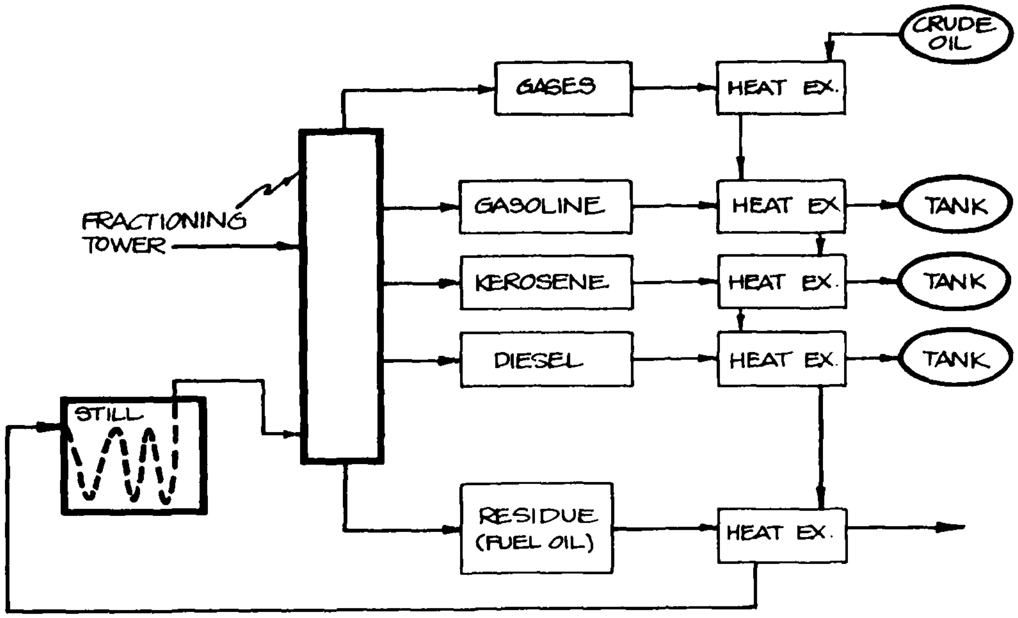

Fig. B-10. Petroleum distillation with a fractionating tower.

Alternate means of erecting a fractionating tower could include:

(1) Erect concrete pipes (4 ft diameter) vertically, and line the inside with steel sheets

(2) Use 3-ft diameter steel pipes (of the type used in trans-continental pipelines). If the expected service life is short, water pipes might be adequate.

(3) Use tank car shells and connect them vertically.

(4) Other options will include vertically connecting cylindrical vessels of about 3-ft diameter to give a sufficient height (about 30 ft).

The height requirements will depend on flow rates, heat distribution, etc. Temperature control along the height of the fractionating tower is extremely important. If there are problems with temperature control, a less elegant but surer method would be separation by successive flash

fractionation, as shown in Fig. B-11. In this scheme, the lowest boiling product is vaporized in tower No. 1 by reboiler heat at the bottom of tower No. 1, and successively higher and higher boiling materials are removed in the remaining towers. This sytem offers the flexibility of being able to add on more towers, along with easier temperature control, as more products are desired.

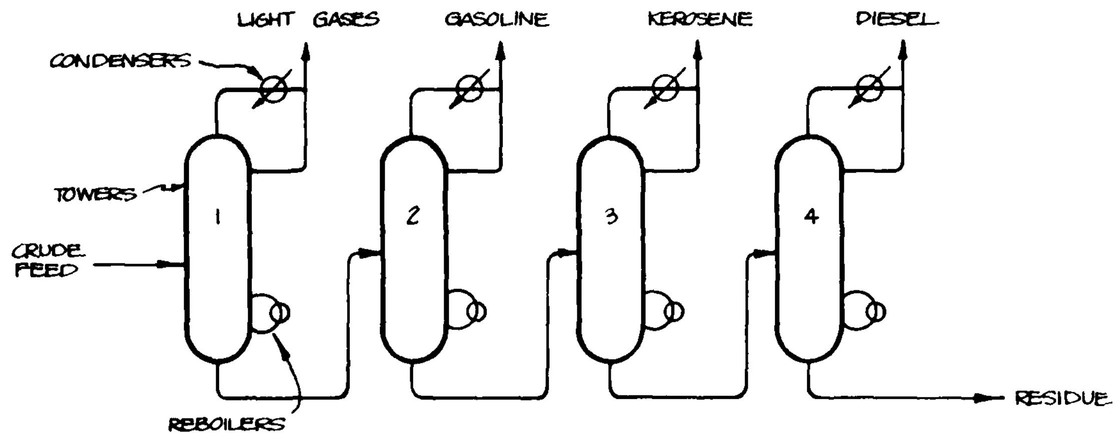

Fig. B-11. Separation by successive flash fractionation.

Sample Calculation. — The calculation results from fractional distillation of a Pennsylvania type crude, with steam injection, are shown in Fig. B-12. The capacity is 1,200 barrels/day. At the selected datum temperature* 576°F the gasoline, naphtha, kerosene, and diesel are vapors, and the reduced crude oil is a liquid.

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* The datum temperature is the temperature about which the design of the tower hinges. By using this datum, the heat balance consists of the heat required (1) to vaporize the fractions, (2) to cool each product from the vaporizer temperature to its withdrawal temperature, (3) to condense the products that are withdrawn as liquids, and (4) reflux computation where necessary.

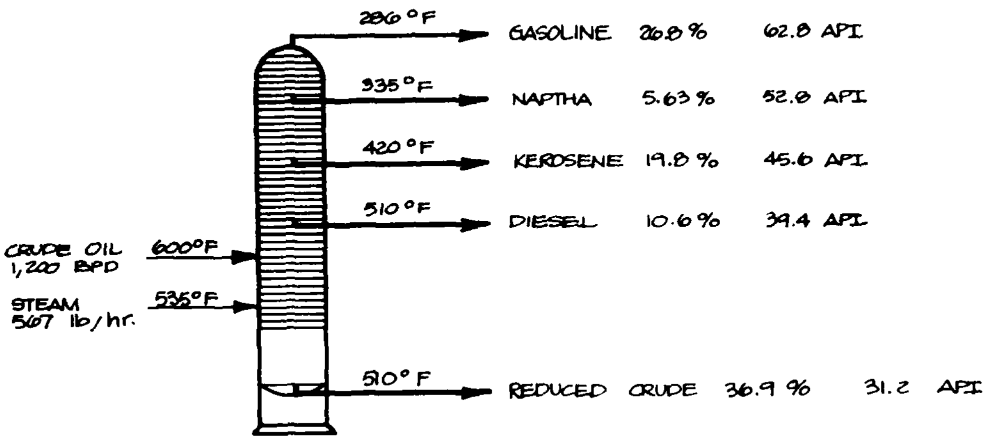

Fig. B-12. Simple tower system with materials balance.

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The report describes the initial testing of a self-help manual developed for application by U.S. industry to help reduce industrial vulnerability to a nuclear event; it is expected to have application to natural disasters as well.

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